Rainwater Harvesting and the Scope of Enhancing Ground Water Table in Dhaka City

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Introduction

The water supply system in Dhaka has been facing a major problem for quite some time and is considered to be one of the worst of the South Asian cities. According to a study by the Groundwater Monitoring Survey Report of Bangladesh Agricultural Development Corporation (BADC) and Institute of Water Modeling (IWM), the groundwater level of Dhaka City is falling by three meters per year. Groundwater has already receded by fifty meters in the past 40 years bringing the current level to sixty five meters below the ground. The supply-demand gap is approximately 500 million liters per day. The water supply situation of the city is perpetually in the grip of a crisis, especially in the dry season when serious water shortages afflict the city. The increasing demand for water has resulted in large scale withdrawal of groundwater in a situation of lowering capacity of the city in recharging due to continuous fall in the amount of green spaces. This has led to serious problems with both quantity and quality of groundwater.

Considering the gravity of the water supply problem, the aim of this paper is to investigate how the ground water level could be enhanced and conserved by adopting specific policy measures in recharging the underground water table. It is estimated that about 150 billion liters of rainwater could be harvested during the monsoon season alone. Rainwater harvesting offers a low-cost system in collecting and storing rainwater for year-round use and could be a cost-effective and practical solution to ease Dhaka's water crisis. It is estimated that rainwater harvesting (RWH) systems could supply more than 15% of Dhaka's requirements. Water can be stored for four to five months without bacterial contamination is an important fact given that 110,000 children in Bangladesh die of waterborne illnesses every year. The research explains the growth of Dhaka and its water supply profile including water scarcity, demand and supply gap in the face of declining groundwater. The paper provides an overview of possible solutions considering alternative water supply and focuses measures of water conservation as well. It highlights on the rainwater harvesting techniques and potentiality of recharging groundwater with some case studies. The study is based mainly on secondary sources of information.

Growth of Dhaka throughout the History

Dhaka as a capital city has a history of more than 400 years, and at present it is the 9th largest city in the world. The city began functioning as a provincial capital of the eastern wing of Pakistan in 1947 and recorded a population of only 0.28 million in 1951 in an area of 35 sq. m., while in independent Bangladesh, the city started working as a national capital with a population of 1.2 million in 1971. Since then Dhaka has been experiencing an influx of migrants from rest of the country. A study shows that since 1963, the population of Dhaka has grown by thirteen times and the city expanded physically into surrounding low-lying areas in an unplanned and uncontrolled manner.

Dhaka became the capital of Bengal in 1610 A.D. Mughals reconstructed the old fort, established Lalbagh Fort and the Chawk and started developing the city around the area of Fort and Chawk. A sizeable number of settlements grew around there in the early years of Dhaka as the capital. In 1640, Dhaka city area was 10 sq.m. and population was only 10,000. Owing to the battle of Palasy, the city population shrank dramatically within a short period and Dhaka became smaller than Calcutta. In 1765, the British declared Calcutta as an important administrative center. In 1850, the area of Dhaka was 15 sq. m. and population was less than 50,000. The growth of Dhaka was much slower during the period.

As the national capital of newly independent country, Dhaka started growing from the beginning as the main administrative and commercial hub of the country, and since then it started experiencing phenomenal growth in population and physical size. In 1974, Dhaka city area was about 50 sq. m. with a population of 1,680,000.

Dhaka is now one of the most densely populated and fastest growing cities in the world. The present population in Dhaka Metropolitan Development Plan (DMDP) area is estimated to be around 15 million with an area of 590 Sq. m and is likely to exceed 18 million by 2015 and 22 million by 2025. This indicates that the city will continue growing in future in a similar fashion as in the immediate past. Table 1 shows the periodic growth of population and demand and supply for water in Dhaka city. Figure 1 presents the growth of Dhaka city in different periods.

Table 1: Growth of population, and demand-supply situation of water in Dhaka city

Year	Population (% of decennial growth)	Demand (mld)	Supply (mld)	No. of DTW
1971	1.2	60	180	47
1981	4.6	550	300	87
1991	7.3	1000	510	140
2001	9.4	1600	1220	336
2011	12.2	2200	2020	554
2021	18.0 (projected)	2860 (projected)	-	-

Source: BBS and DWASA, 2011.

The present area of jurisdiction of Dhaka city corporation area is 258.78 sq km, DND area is 56.79 sq. km and Narayanganj pourashava area is 33 sq. km. The expanded area of Dhaka includes more than 1000 sq. km covering Kanchan Pourashava in the east, new areas of Savar Upazila in the west and Gazipur & Trishal Upazilas in the north, and upto Maowa bridge in the south.

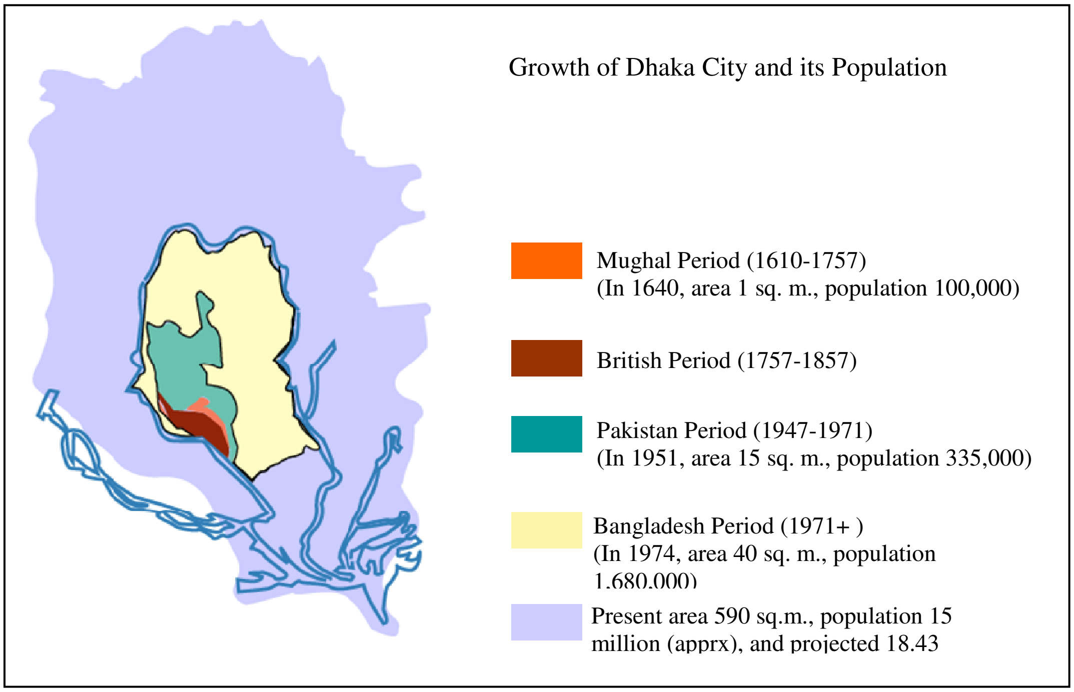

Fig. 1: Growth of Dhaka city and its population size in different time periods.

Water Profile of Dhaka City

Water Supply

Historically, most of Dhaka's water supply comes from its two peripheral rivers, the Buriganga and the Shitalakkhya. But as population has increased and industry has expanded, the river water has become contaminated with indiscriminate disposal of domestic, commercial and industrial waste as well. Today, groundwater is expected to satisfy over 85% of the city's water supply.

The authorities responsible for water supply in Dhaka City area are the Dhaka Water Supply & Sewage Authority (DWASA) and the Department of Public Health and Engineering (DPHE). The DWASA looks after bulk supply, distribution and pumping, metering and billing of potable water to domestic and commercial connections and treatment of water as well,while the DPHE is concerned only with the shallow and deep tube well.

The water supply system of DWASA dates back to 1874 at Chandnighat (first surface water treatment plant established by Nowab Khaja Abdul Gani) and new water sources have been identified to augment the supply to meet the ever-increasing demand for water. Surface water from rivers is directed and treated at different plants of Dhaka city. The total installed and treatment capacity is 47.54 mld. Three water treatment plants exist at Sayedabad with a capacity of 225 mld, Chadnighat with 39 mld and Godanail and Sonakanda of Narayanganj with 28 mld. The treatment process involves sedimentation followed by pressure filtration and chlorination.

The present water demand is estimated to be 2470 mld (based on a per capita requirement and calculated by DWASA). According to estimation in June 2009 by DWASA, total water supplied by DWASA is 1930 mld. To meet the growing demand of water for both the increase in population as well as increase in floating population, supply from surface water is 292.5 mld (13%) while supply from gound water is 1679 mld (87%). Water supply in Dhaka city is heavily dependent on ground water. There are plans for augmenting the water sources further by tapping the rivers Dhaleswari and Pabbar in the coming years as part of the projects. In 2030, estimated water demand for Dhaka will be 4990 MLD (* source: IWM & DWASA).

Surface Water Supply

The cost of water supply after surface water treatment is very high as water is mainly sourced from the Shitalakkha river and pumped up to the residential areas after treatment. The energy cost incurred in order to raise water to head of about 5800 m results in a high cost of production of Tk. 35/KL. This cost is incurred by DWASA at the rate of Tk. 9.20 per KL. DWASA, in turn, charges Tk. 6.60 per KL of water for domestic purposes even though DWASA incurs an additional cost of Tk. 2.70 per KL towards operation and maintenance costs. Therefore, water supply is heavily subsidized to consumers, more than 70%. In 2010, the water charges were revised from flat rates to slab rates and since then, the charges are revised annually over past three years. The local distribution system of core area of Dhaka is more than 100 years old. Leakage losses are high due to leakage from corroded and damaged old pipes and leaking joints. Moreover, there is also considerable loss arising from theft and illegal tapping of water. According to DWASA statement, leakage losses are more than 3855

Turag river in the north-west, Balu river in the north-east, Sitalakhya river in the south-east, Dhaleswari river in the south and Buriganga rivers in the north-west are the peripheral rivers of Dhaka City. These rivers act as the receivers of storm water, municipal, and industrial wastewater from Dhaka City. These rivers are also connected with over 300 outfalls of domestic wastewater and industrial effluent from Dhaka city. Effluents are discharged indiscriminately without any primary or secondary treatment. So there are plans for augmenting the surface water sources from 13% to 50% in 2015 and 50% to 70% in 2020 through installation of new four surface water treatment plants at Narayanganj SWTP (from Shitalakhya), Khilkhet (from Meghna), Pagla SWTP-I (from Padma) and Pagla SWTP-II (from Padma) by tapping the rivers Shitalakya, Meghna and Padma in the coming years. (Source: IWM & DWASA). Government has initiated to implement Saidbad SWTP Phase II, Keraniganj SWTP and Khilkhet SWTP to increase supply of 850 MLD and 1350 MLD by 2015 and 2020 respectively.

Groundwater Supply

Water supply in Dhaka city is heavily depended on ground water. There are a total of about 546 deep tube wells are in operation in the Dhaka city area. As groundwater has been used for water supply since the creation of the city, water table in the deeper aquifers has declined considerably.

45 DTWs in deeper aquifer are in operation and another 50 DTWs have been planned. Water is pumped from the deep aquifers more than 200 m and total water connection in Dhaka are 282,691 with an estimated pipeline of 2664 km. Impact of abstraction from deeper aquifer (>200m) is now being monitored. 230 mlpd day could be abstracted from the deeper aquifer of Dhaka city though close monitoring is required before further abstraction while 300 mlpd could be safely abstracted from well-field in Singair area (Ref: DWASA & IWM).

DWASA has committed to reduce dependency on ground water from 87% to 50% by 2015 and in this respect DWASA needs implementation of its projects as planned and discussed in the dialogue. An inclusive and well planed coordination body has planned to be formed involving all related Ministries as mentioned to solve water problems in Dhaka city.

State of Urban Water Environment

The following aspects are relevant for Dhaka City in respect of urban water environment:

- Rapid population growth including slums
- Mismanagement or lack of management
- Interest in pipe lines and huge investments
- No proper pricing for water
- Change in land use pattern
- No control on groundwater extraction

Water Scarcity

The supply-demand gap is approximately 500m liters per day. Every summer, newspaper reports quote residents residing in the southern sectors of Dhaka city complaining about the shortage of drinking water. Residents have also held a series of protests in several parts of the city. The situation is so problematic that in the summer of 2010, the Government of Bangladesh deployed troops to manage water distribution in Dhaka. In 2011, Dhaka city was getting supply of 2000 mld per day against the requirement of 2470 mld. The cost of production (Tk.8.95/kl) of water is generally higher than charges for water (Tk.6.66/kl) in Dhaka City, which indicates that the government is incurring a loss.

Future Demand

The water shortage is likely to get worse in the coming years as the population is already more than double the planned capacity for the city. In addition, there is a large floating population and a slum population that is being rehabilitated. There are plans for a number of neighbourhood and other new satellite towns projects that will swell the population of Dhaka city. The demand of water for other purposes such as industrial and commercial will also increase concurrently with the demand for domestic water demand. Table 2 shows the demand supply situation of water in the city.

Table 2: Water demand and supply of Dhaka city

Population (as per BBS for 2011 – permanent + floating)	16,800,000
Present water demand (based on 2011 population @ 135 lpcd)	2,268 mld
Average water supplied (As per IWM survey in 2010)*	2,020 mld
Transmission & Distribution losses	>35%
Net total water supply (after leakage losses)	1,313.0 mld
Net per capita supply	100 lpcd
Supply Frequency	120 minutes on alternate days in lean period and 90 minutes Daily on non-lean period

Source: DWASA

Decline of Groundwater

DWASA has committed to reduce dependency on ground water from 87% to 50% by 2015 and in this respect DWASA needs implementation of its projects as planned and discussed in the dialogue. An inclusive and well planed coordination body has planned to be formed involving all related Ministries as mentioned to solve water problems in Dhaka city. At present, 45 DTWs in deeper aquifer are in operation and another 50 DTWs have been planned. Impact of abstraction from deeper aquifer (>200m) is now being monitored (Ref: DWASA & IWM). There is a general acceptance of the fact that no further abstraction from upper aquifer (100-200m) is viable I Dhaka City.

Dhaka City is already sourcing 87% of its water supply from groundwater and there is a considerable decline in the groundwater levels of the deep aquifers (Table 3). According to a study of BADC, pre-monsoon data for the period 1996 to 2006 (10 years), southern part of Dhaka city shows a maximum decline of 35m and in northern part of Dhaka, the fall has been of the order of 20m. The remaining parts of the city show an average decline of 3 to 8 m. To cope up with the decline, DWASA is drilling deeper. Every year, about 15% of such tube wells become defunct.

Table 3: Ground water depletion situation in the capital of Dhaka

Year	Water Level below the Surface
1996	27.60
1997	28.15
1998	30.45
1999	31.86
2000	34.18
2001	37.78
2002	42.00
2003	46.24
2004	50.60
2005	57.42
2006	59.72
2007	61.18
2008	64.27
2009	67.12

Source: Groundwater Monitoring Survey Report, BADC.

Possible Solutions and Way Ahead for Rainwater Harvesting

Water crisis in Dhaka city is a usual phenomenon since last several years. Most other cities of Bangladesh are also water-stressed. Every summer, there are riots, protests in different parts of Dhaka city. But water availability will not grow in parallel leading to water stress and resultant conflicts. Disappearance of urban water retention area and other water bodies leads to flooding when rains come. Due to encroachment of water bodies, land filling of water retention areas and as well as water scarcity in the city, there is a need for focused and large-scale action on rainwater harvesting. There is a need to put in place a number of measures to create awareness among the people about the importance of water and advise them to use water carefully and wisely. This requires research, policy measures (legal, financial), capacity building and general awareness and education of the people. Water conservation measures generally include:

(a) Rainwater harvesting;

(b) Recycle and reuse of water; and,

(c) Reducing water use i.e. demand side management measures.

The first step is to create a central authority to coordinate all water conservation and augmentation measures (Rainwater Harvesting or Water Conservation Cell). The next step is to define clear and definite short-term and long-term measures and targets, identify funding sources and secure adequate funding. Bulk users and institutional buildings must be targeted first. The Government of Bangladesh has enacted some measures to incorporate some policies as well as rules and regulations in the Building Construction Rules and National Building Code, making it mandatory for all large catchment buildings to have rainwater harvesting systems.

Rainwater Harvesting: The first step to encourage rainwater harvesting in the city is to create a Rain Centre that will serve as a central repository of information on all aspects related to rainwater harvesting. The Rain Centre will have posters, models and training facilities. It will be staffed with technical experts to provide technical help to common people. The Rain Centre will also serve as a centre for providing training and capacity building to a cross-section of people from masons and plumbers to planners, architects and engineers. A key system that must be set up will be an Inspection and Maintenance program to ensure that all rainwater harvesting systems are kept in good order. A systematic program to regularly clean and maintain the systems must be put in place.

Recycle and Reuse of Waste Water: Domestic waste water is waste eater that is primarily generated by households, which consists of water from baths, showers, sinks, dish washers, washing machines and toilet and does not include industrial or agricultural waste water. This source of wastewater is about 99 percent water by weight and is generally referred to as influent as it enters the waste water treatment facility. Treated wastewater if handled properly, can be a valuable agricultural input as it contains several nutrients and is a vital source of fertilizer. It is desirable that in the decentralized treatment system, the treated waste water is recycled/ reused for irrigation and flushing; availability of sufficient land in the form of parks, gardens, trees and provision of recycling the treated effluent for flushing have to be ensured. Recharge of ground water is one of another ways of reusing waste water. A crack-free 3 meter thick soil layer above ground water is sufficient to prevent organic pollution.

Reducing Water Use Introducing Water Efficient Fixtures: There is an increasing trend the world over to reduce the use of water by designing water efficient fixtures. In countries like Australia, Canada US and even India, laws have been brought in to make it mandatory to replace old fixtures that use more water with water-efficient fixtures. Therefore, the Chandigarh administration should also look at policy initiatives to facilitate the change over to the use of water- efficient fixtures. These can include labelling of water efficient fixtures, rebates on the fixtures, rebates on water bills. In addition, the Administration can go in for a focussed replacement programme of all older, water guzzling fixtures. The most common water efficient fixture is the flush toilet and in Dhaka city, low-flush or dual flush toilets are already being used widely. Water taps, washing machines are other fixtures where efficiency can be brought in. Government or concerned department should initiates some policies or awareness programs which will help in motivating consumers to switch over to the use of water efficient fixtures.

Measures of Water Conservation

Short-term Measures: This will include legal, administrative and financial measures on the one hand, and awareness creation and capacity building on the other. They go hand in hand and must be initiated together. To catalyse citizens and public institutions to become water-wise, legal and administrative measures can be put in place. These include amendment of by-laws to make water conservation measures mandatory, financial and administrative incentives such as rebates on water bills, property taxes, award programs etc. Pricing of water is a key instrument to ensure that consumers use water carefully.

Long-term Measures: A focussed program to encourage research on such issues as hydro-geological and rainfall mapping, filters, technological tools must be instituted. Detailed maps of each zone can be created for recharge zones, flood-prone areas, water quality and water bodies that can be revived etc. Detailed studies can be initiated using GIS, satellite imageries. Before exhorting the public to use water wisely, the Administration must lead by example by instituting measures for wise-use of water in its own buildings. Rainwater harvesting must be implemented in all government buildings and public spaces such as parks, stadium etc.

Rationale for Harvesting Rainwater in Dhaka City

Most of the urban centers in Bangladesh are water guzzlers, and particularly Dhaka city taps the deep, confined aquifers for water supply. A confined aquifer can only be recharged naturally in places, where it is exposed to the surface. In Dhaka, natural recharge of confined aquifers is not taking place and yet, water is being pumped out from these aquifers.

The deep, confined aquifers of Dhaka City are therefore on the decline. To ensure long-term sustainability of water sources for the city, rainwater harvesting is a simple and effective solution. It can be done using roads, roundabouts, parks, rooftops, and paved areas, almost the entire city.

Rain water harvesting can be done either by storing the harvested rainwater or by recharging the aquifer. In Dhaka City, rain water harvesting is constrained by the following factors:

Hydro-geological profile consists of layers of clay and sand in different thicknesses. This layered sequence compels finding the intervening sand lenses for recharge. DWASA is using only water from deep, confined aquifers, which do not get recharged naturally.

DWASA is not using the shallow unconfined aquifer. As there is a steep incline from northern to southern sectors, the shallow unconfined aquifer in the southern sectors get recharged naturally and there is water logging in the monsoon season in these areas. Therefore, rainwater harvesting by recharge to the shallow aquifer cannot be undertaken. Rainwater harvesting by recharge can only be undertaken to the deep, confined aquifers. As there is only 58 rainy days in a year, it is not possible to collect enough rain water in storage systems that can be used for a longer period.

Rainwater Harvesting Potential in Dhaka

The rainwater harvesting potential of Dhaka City, with an area of 1580 sq km, assuming a co-efficient of 50%, and the average annual rainfall of 2000.0 mm (appx) is 158.0 million litres or 41.74 million gallons. This is more than the water pumped out of aquifers and therefore, harvesting and recharging rainwater will go a long way in contributing towards sustainability of water supply.

Ways and Means of Rainwater Harvesting

- o By recharging the deep, confined aquifers
- o By storing water in tanks, ponds and water bodies.

Recharging Deep, Confined Aquifers

Recharge to deep aquifers can be undertaken in a number of areas across the city – from roads to green areas to airports. The storm water drain network is the most suitable for this purpose, as rainwater from the entire city is tapped for recharge. Figure 3 depicts the DTWs location in Dhaka city, where it is observed that the tube wells have been drilled all across the city and concentration in some places is very high.

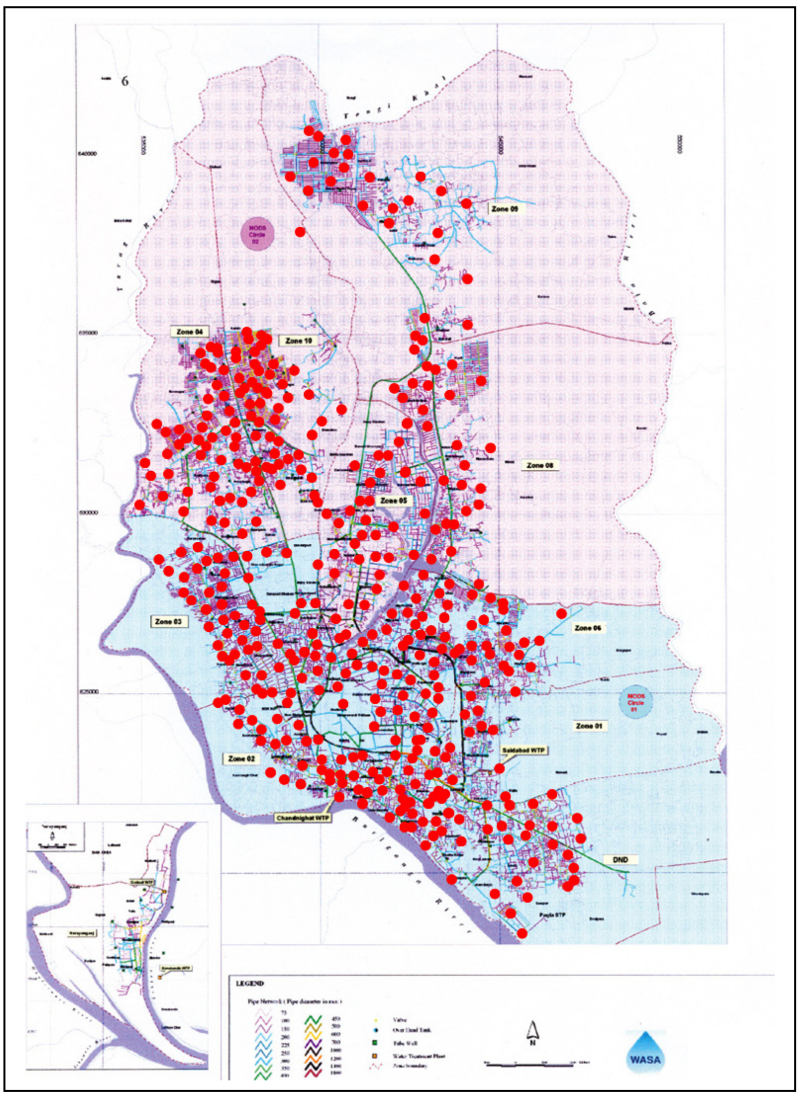

Fig. 3: Location of DTWs and Water Supply Distribution System in Dhaka and Narayanganj.

Recharge structures can therefore be built across the city.

- The simplest way to do recharge would be to tap the storm water drain network. Structures can be built next to the storm water drain by tapping the water from it and using the rainwater to recharge the aquifer after proper filtration.
- There is a concentration of DTWs in the areas around Mirpur. As this area has good sandy layers with appreciable thickness, the area has high potential for rainwater harvesting.

Recharge structure must be shallower than the ground water table so that the water from the recharge structure is able to permeate through layers of soil, thus undergoing further filtration, before it joins the water table. Figures 4 and 5 present the model situation on how the recharge of rain water can be made.

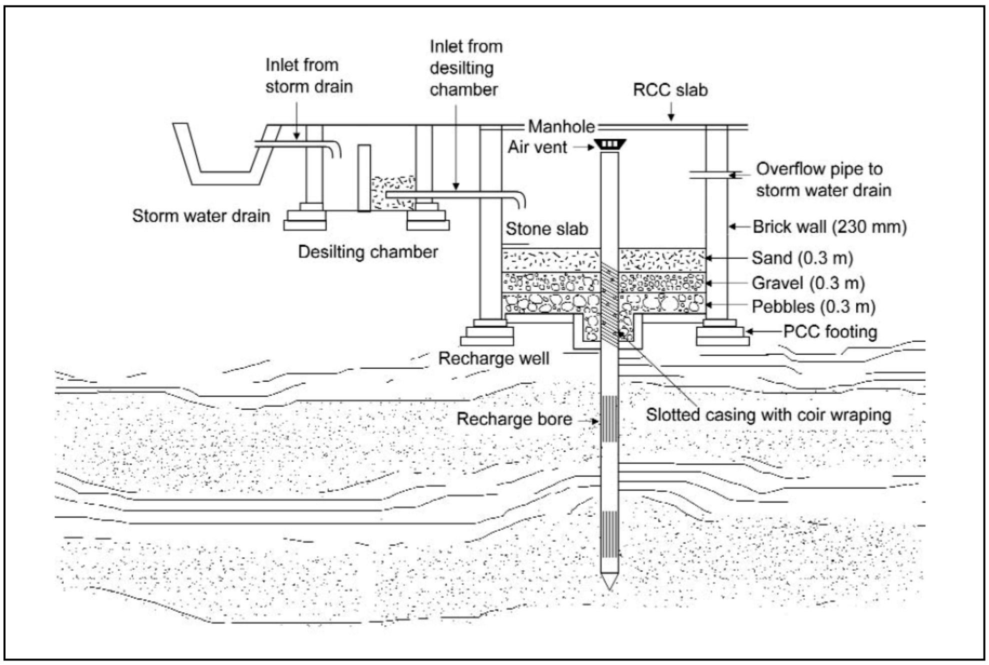

Fig. 4: Cross Section of Recharge Well with Desilting Chamber.

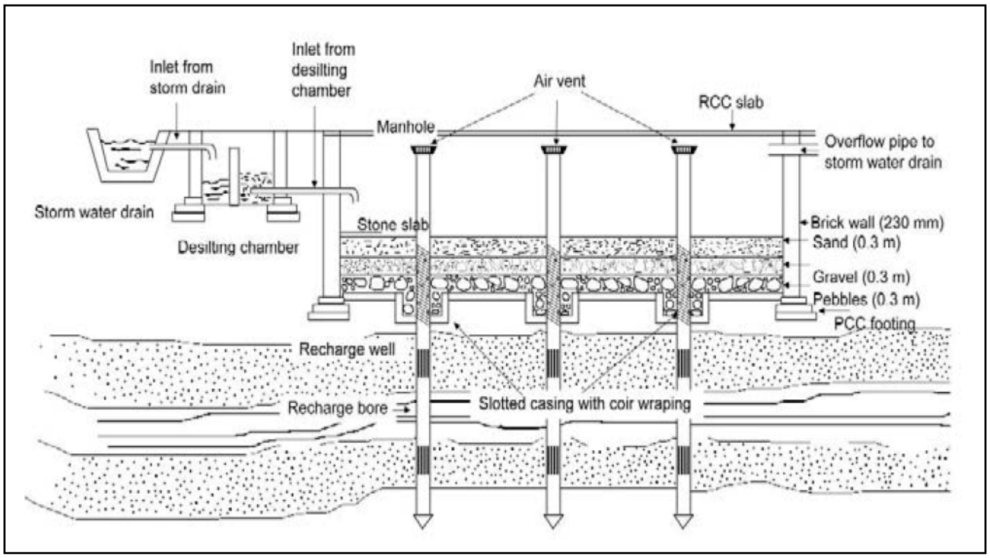

Fig. 5: Cross Section of Recharge Trench with Desilting Chamber.

Storage

In addition to recharge, storage structures can be built for rainwater harvesting. Storage in underground or over the ground tanks can be undertaken in the commercial areas, institutional areas like schools, colleges and other institutions, which have large roof areas. Storage can also be undertaken in green areas of Dhaka City by constructing ponds and larger water bodies. DCC could build ponds or water bodies near the Botanical Garden as the soil is suitable to create such water bodies.

Planning for Rainwater Harvesting in Dhaka

Rainwater Harvesting Potential

The rainwater harvesting potential of Dhaka City, with an area of 1580 sq km, assuming a co-efficient of 50%, and the average annual rainfall of 2000.0 mm is 158.0 million litres. This is more than the water pumped out of aquifers and therefore, harvesting and recharging rainwater will go a long way in contributing towards sustainability of water supply.

Runoff (Potential for Harvesting) =A x R x C

Where,

A =Area in sq. m

R = Annual Rainfall in mm

C =Runoff Coefficient

Example,

A =200 m2

R = 2000 mm

C = 0.80

Potential for Harvesting = 320,000 liters

Dhaka Average Annual Rainfall: 2000 mm approximately

Dhaka Current Annual Demand: 2000 mld approximately

Rainwater Harvest Potential 15% of the annual demand

Catchment Areas for Rainwater Harvesting

Local water supply administration (DWASA) is tapping the deep aquifers for groundwater from all sectors in the city. Therefore, rainwater harvesting can be undertaken to recharge the deep aquifers in the city. In order to do this, the sandy layers in the deep aquifers must be identified and recharge undertaken.

The areas suitable for rainwater harvesting are as follows:

Roads and Roundabouts: Recharge along storm water drains to both recharge rainwater as well as prevent flooding.

All Green Areas: Recharge where suitable and store where hydrogeology is not suitable. Stored water can be used for horticulture. Ponds can be constructed to harvest and use rainwater as in Botanical Garden.

Institutional areas, such as Dhaka University, Ministry Complex: Recharge where suitable and store where hydrogeology is not suitable. Stored water can be used for gardening.

Commercial areas: Store in underground tanks for non-potable use.

Schools, colleges and religious places: Storage and recharge. Stored water can be used for horticulture and other non-potable uses.

Industrial areas and Airport: Water from rooftop catchments to be stored that can be used for industrial purposes. Overflow of rooftop water can be recharged. Water from rooftops and hangars to be harvested in storage tanks to be used for non-potable purposes

Roads and Roundabouts

The total land area for major roads in Dhaka City is about 145.0 sq km. Recharge can be done either by constructing recharge trenches or recharge wells. Water from the storm water drain will be tapped and channeled into a desilting chamber from where it will be led into a recharge trench/well. The recharge bore will have slots for the sandy layers and will be blind in the clay layers. As the water will be recharged into the aquifer directly, there is a need for good filtration systems. Annual desilting of the desilting chamber and cleaning of the filtration materials is mandatory to ensure that the system will be in good working order.

Rainwater Harvesting Potential at Mohakhali Flyover

The Catchment Area of Mohakhali Flyover is 1,18,000 sq.m. with a rainwater harvesting potential of 28.80 ml per annum.

Green Areas

Harvesting rainwater and storing in large ponds will ensure sustainable supply of water for green areas. Ponds can be constructed at the lowest elevation so that water flows to the pond by gravity. Soil properties of eastern part and south-western part of Dhaka city is suited to construct such ponds as the top soil is clayey. Recharge structures can be additionally constructed to channelize the overflow. For instance, the Botanical Garden has already constructed two such ponds. For instance too hold water, a pond measuring 25 m x 11 m and a depth of 4 m can be built, that will have a capacity of 11 lakh litres. The sides of the walls can be strengthened by planting indigenous varieties of plants such as Vetiver, Apluda etc that will serve to hold the soil as well as help in arresting silt. Native species can also be planted in the channels leading to the pond to arrest silt. 100 mm rain falling on 1 ha of land means 1 million litres of water.

Institutional Areas

In the institutional areas, both storage and recharge can be undertaken because of the availability of large rooftop areas as well as paved and unpaved areas. Over or underground tanks can be constructed where rooftop water can be directed, filtered and stored. These can be used for non-potable purposes. Overflow of the water can be channelised into recharge structures. Recharge structures will be undertaken based on the nature of the aquifer geometry as per borehole logs. Substantial water can be collected from large institutional buildings. For instance, the roof area of the ministry building has an approximate roof area of 900 sq m. From this about 1.44 million litres can be harvested annually. Similarly, the High Court building has an approximate roof area of 180000 sq m and approximately 880 million litres can be harvested annually. As there are large open spaces available around such public buildings, it would be feasible to construct underground tanks of a minimum capacity of 0.15 million litres to use for non-potable use.

Rainwater Harvesting Potential at Dhanmondi R/A

The Catchment area for each one bigha plot is 900 sq.m. with approximately 150 persons per holding, and a water demand of 8.87 million liters per annum. Rainwater harvesting potential per annum is 1.44 million liters, approximately 15.0% of the annual demand.

Commercial Areas: Commercial areas in newly developed part of Dhaka City should be planned in such a way that there are large spaces in front of the buildings that are used for parking. The rooftops of the commercial areas can be used to harvest a good amount of water. Large tanks of a minimum of 1 lakh litre capacity can be constructed in front of the commercial spaces under the parking areas as described above. This water can be used for non-potable purposes. The total commercial space as per land use records of DAP is 179.00 sq km.

Schools, Colleges and Religious Places: Schools and colleges have large rooftop areas from where it is easy to harvest rainwater and store it for non-potable use. Large tanks of a minimum of 0.15 million litre capacity can be constructed for non-potable use. The overflow can be used to recharge groundwater. Water from paved and unpaved areas can also be used for recharging.

Industrial Areas and Airport: In the industrial areas and airport, rooftop areas can be used for harvesting water that can be either stored or recharged.

Rainwater Harvesting Potential at Hazrat Shah Jalal Int'l Airport, Dhaka

Catchment Area: The total area is comprised of 550,000 sq.m. including the runoff area of180,000 sq.m. and apron and pavements area of 320,000 sq. m. The per annum rainwater harvesting potential of the airport area is 880 ml.

Rainwater Harvesting Practices in Overseas Countries

Rainwater harvesting is being practised in both developed and developing countries of the world. Some such experiences are presented below.

Singapore

Singapore harvests water from 60% of land i.e catchment area for RWH stored in 14 reservoirs. By 2011, it will have 3% recycled water diverted to water supply reservoirs.

Chennai, India

- From 1994, RWH was made mandatory for buildings with 4 floors;
- In 2001, it was made mandatory for new buildings irrespective of number of floors.
- In 2003, it was made compulsory for all the buildings (existing and new) in all cities, towns and municipalities and town panchayats.
- Empowered the Municipal Corporaiton of Chennai to implement RWH, where not implemented and recover costs from the owner; also to disconnect the water supply.
- Strict monitoring by physical inspection
- Improved water levels as well as water quality

Delhi, India

- In 2001, RWH mandatory for new buildings of 100 sq m and plots of 1000 sq m
- Plans are approved after inspection
- Ban on drilling of bore wells
- In 2009, directives to all its departments, local bodies and public sector undertakings to install rain water harvesting systems in their buildings

Hyderabad, India

Rainwater harvesting has been made mandatory in all new buildings of Hyderabad in India with a plot area of 300 sq m. Specifications for pits were provided.

- Liable for penal action for non-compliance
- Approval of planning given after inspection
- However, criticism is that people simply dig pits in the name of RWH to get approval.

Australia

In 2011, the country made a target for having 25% rainwater; 45% recycled water; 14% water conservation; and 16% drinking water. This is an important policy matter that can be considered by policymakers of Bangladesh.

Analysis of Alternatives

Several ways of improving water availability in both surface and underground levels are discussed in this paper. These alternatives provide some ideas on ground water recharge and rainwater harvesting that can be considered by the city development authorities. Harvesting and conservation of water could improve the existing water situation in the city though recharging the water into underground level. This might require adequate measure for keeping the water table clean and safe. However, the options discussed in the research for resolving water crisis in the city may provide useful thoughts on the matter. It is encouraging that the draft Bangladesh National Building Code (BNBC), 2013 has addressed the issue for undertaking measures in future. The international experiences also provide interesting ideas on the reduction of risks in undertaking measures on rainwater harvesting and ground water recharging as discussed above. For Dhaka, some measures may really be necessary in future in order to save the city from severe water crisis and related environmental problems.

Conclusion

In the face of growing demand for water in the city, the authority has no alternative but to look for a permanent solution of enhancing the capacity of recharging the rainwater into underground water table. It is hoped that this paper has highlighted some ideas that are also being discussed in the policy and professional domains for quite some time from desperation of finding out a way for solving the water problem in Dhaka City. This might be possible through adopting some measures of rainwater harvesting, conserving existing surface water sources and creating more green spaces in the DMDP area. It is expected that a pragmatic solution of the problem will eventually be evolved for realistic purposes.

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