Journal of Scientific Research & Reports
13(6): 1-7, 2017; Article no.JSRR.31866
ISSN: 2320-0227

SCIENCEDOMAIN *international*
www.sciencedomain.org

Potentials of Rainwater Harvesting as an Alternative Water Supply System in Dhaka City

Asma Ul Husna[1*] and Md. Saliur Rahman[2]

[1]Development Studies Discipline, Khulna University, Bangladesh.
[2]Institute of Business Administration, University of Dhaka, Bangladesh.

Authors' contributions

This analytical research work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2017/31866
Editor(s):
(1) Leszek Labedzki, Institute of Technology and Life Sciences, Kujawsko-Pomorski Research Centre, Poland.
Reviewers:
(1) Abdol Aziz Shahraki, The Royal Institute of Technology, KTH. Stockholm, Sweden and University of Sistan and Baluchistan Iran.
(2) Frederick Amu-Mensah, CSIR Water Research Institute, Ghana.
Complete Peer review History: http://www.sciencedomain.org/review-history/18760

Data Article

Received 28th January 2017
Accepted 1st March 2017
Published 24th April 2017

ABSTRACT

Dhaka city is characterized by densely populated unplanned growth of predominantly building infrastructures. Concerned water supply authority is unable to fulfill the water demand. Shortage in supply and unavailability of groundwater is increasing day by day. In such situation rainwater harvesting is thought to be the next alternative option. Rainwater Harvesting System (RWHS) is basically a simple, technically feasible and socially acceptable system to capture and use rainwater for various purposes. This study intends to assess the potentiality of rainwater harvesting for domestic use. Rainwater harvesting potential equation calculates the daily potential rainwater supply for residential apartments. Testing of rainwater quality suggests that it is convenient to use rain water only for non-potable uses. In order to get benefits of rainwater harvesting some compulsory regulatory measures need to be imposed in the building development process along with awareness building activities. Therefore this paper identifies various challenges and problems related to explore full potential of rainwater harvesting in Dhaka city.

Keywords: Rainwater harvesting; potential rainwater supply; rainwater quality; Dhaka city.

**Corresponding author: E-mail: shapla_urp08@yahoo.com;*

1. INTRODUCTION

Dhaka is considered as one of the most densely populated cities in the world. Due to ever increasing growth and unplanned urbanization, city dwellers are now facing enormous problems. Among these problems, water crisis is an acute problem. Demand of water is increasing with the increasing rate of population. But the sources are limited [1]. Rainwater harvesting is not so much well utilized in the urban areas of Bangladesh, and could be an effective solution considering the existing water crisis problem of Dhaka city. Rainwater harvesting is the practice of collecting water that falls as rain before it has a chance to soak into the ground and become groundwater or run-off into a watercourse and become surface water. Rainwater harvesting offers an affordable, simple, sustainable and reliable alternative water source.

Dhaka Water Supply and Sewerage Authority (DWASA) is the only public utility agency to supply potable water in Dhaka city. Dhaka Water Supply and Sewerage Authority (DWASA) water supply system is mainly depended on ground water sources where about 87 percent of the supplied water is extracted from 603 deep tube-wells. Such extensive dependency on groundwater enhances a very high depletion rate of ground water table. Dhaka city has been experiencing a sharp decline in ground water table. According to the statistics of Bangladesh Water Development Board (BWDB), groundwater level in Mirpur dropped 53.75 meters between 1991 and 2008, while the decline was 18.59 meters in Mohammadpur, 37.4 meters in Sabujbagh, 8.22 meters in Sutrapur, and 14.14 meters in Dhaka Cantonment during the same period [2]. The ground water is getting low day-by-day. The city dwellers are suffering because of the lack of water supply although the population or the demand is increasing in an alarming rate. The city is now losing its river, khal and other water bodies. The source of water either is being demolished or being polluted in Dhaka city. Recently rainwater harvesting has achieved great attention in urban areas like Dhaka city to reduce various water related problems such as water scarcity, water logging etc. Government has already taken some initiatives to promote rainwater harvesting not only in institutional building but also in residential buildings of Dhaka city. Dhaka WASA's daily production now stands around 2.10 billion liters against the requirement of 2.30 billion liters. The supply-demand gap is approximately 200 million liters per day [3]. DWASA is facing difficulties in maintaining the adequate level of water supply due to rapid increase of demand and inadequate distribution network to cope with the requirement. Moreover, the water supply network is not modernized periodically. Frequent unauthorized uses and faulty connections result in the contamination of water in its way to reach to the outlets. In this circumstance rainwater harvesting can play a vital role to keep supply in a balanced condition. The aim of this study is to assess the potential of rainwater harvesting as an alternative water supply system for reducing the water scarcity problem in Dhaka city. The potential has been calculated by rainwater harvesting potential equation, using three types of data; mean annual rainfall, area of catchment and run-off coefficient. Quality of rain water has been tested against WHO (World Health Organization) standards.

1.1 Study Area

Dhaka city has 92 wardsunder two local government institutions. Dhaka North City Corporation comprises of 36 wards (1-23, 37-47, 54 and 55), while Dhaka South City Corporation has 56 wards (24-36, 48-53 and 56-92). Dhaka North City Corporation Ward 3 includes the area Mirpur Section - 10 (Block - A, B, C, D), and Mirpur Section - 11 (Block - C). According to the statistics of Bangladesh Water Development Board, groundwater level in Mirpur dropped 53.75 meters between 1991 and 2008. Water scarcity problem is acute in this area. There is 180350 m^2potential residential rooftop areas for rainwater harvesting in this ward.

Table 1. General information of DNCC ward number 3

Total area (km^2)	1.101
Density (person/km^2)	33231
Total population	36587
Total No. of buildings	4749
No. of Pucca Residential Buildings	1230
No. of Pucca Mixed Residential Buildings	125
Total Residential Rooftop Area (m^2)	160361 + 19989 = 180350
Groundwater Depth (m) (2008)	68.5

Source: [4] [5] DNCC, 2013 and BBS, 2011

2. METHODS

2.1 Potential Groundwater Recharge Calculation

Simple hydrologic balance equation has been used in this study to calculate the potential groundwater recharge in the study area.

Re= P-Pe-U

Where,

Re= Potential recharge

P= Rainfall

Pe= Potential evapotranspiration

U= Surface run-off

Blaney-Criddle formula calculates the potential evapotranspiration.

Pe= p (0.46T+8)

Where,

Pe= Potential evapotranspiration

p= Mean daily percentage of annual daytime hours

T= Mean daily temperature

2.2 Rainwater Harvesting Potential Calculation

The following simple equation has been used in this study to calculate theapproximate potential supply of rainwater from a collecting surface.

$S = R \times A \times Cr$

Where,

S = Mean rainwater supply in L
R = Mean annual rainfall in mm
A = Area of catchment in m^2
Cr = Run-off coefficient

3. ANALYSIS AND FINDINGS

3.1 Historical Water Supply Data of Dhaka City

Water supply of Dhaka city is heavily dependent on groundwater extraction where more than 87 percent of the supplied water is extracted from this source. Even though Dhaka city is surrounded by rivers namely Buriganga, Balua and Turag; only 13 percent of supplied water is obtained from these rivers by three small-scale and one large-scale surface water treatment plants. In 2012, the dependency on underground water has been reduced to 74 percent by establishing the second phase of Sayedabad surface water treatment plant with production capacity of 225 MLD (million litre per day); but this type of establishment is highly cost intensive. Table 2 clearly demonstrates the historical water supply dependency of Dhaka city on ground water with the increasing numbers of deep tube-wells operated by Dhaka Water Supply and Sewerage Authority (DWASA). Such extensive dependency enhances a very high depletion rate of ground water table.

3.2 Groundwater Depletion of Dhaka City

Dhaka city has been experiencing a sharp declination in ground water table. This situation is gradually becoming worse day by day. Groundwater has already receded by 50 meters in the past 40 years, bringing the current level to 60 meters below ground. Fig. 1 shows that Dhaka city has been experiencing a sharp declination in groundwater table with about 34 meters lower down during 1996 to 2008 at a rate of 2.91 meter per year (m/y).

3.3 Potential Groundwater Recharge in Dhaka City

It is important to know the natural recharge rate to get the actual groundwater depletion rate. From the following calculation it is found that the potential evapotranspiration rate of Dhaka city is 5.22 mm/d; this data is necessary to calculate the potential groundwater recharge.

Pe = p (0.46T+8) p= .27%
= .27 (0.46*25.5 + 8) T= 25.5°C
= 5.33 mm/d

By putting the value of potential evapotranspiration in simple hydrologic balance equation it is found that the potential groundwater recharge for Dhaka city is 1.27 m/y while the groundwater depletion rate is 2.91 m/y. Therefore, despite sufficient amount of rainfall Dhaka city experiences 1.64 m/y groundwater recharge deficit every year. Considering the existing deficit rate, it is predicted that the groundwater table will go down to 130.38 meters

by the year 2050 at the current extraction and hydrologic patterns.

Re= 2550 – 5.33 – 1275	P= 2550 mm/y
= 1269.67 mm/y	Pe= 5.33 mm/d
= 1.27 m/y	U= 1275 mm/y

3.4 Water Demand Projection

In Table 3 a projection shows that by the year 2030 the future population of Dhaka city would be32.8 million; therefore the total water demand is projected to be 4920 MLD.

3.5 Water Production Road Map to Meet Future Demand

In 2012, with the establishment of the second phase of the Sayedabad surface water treatment plant (SWTP), DWASA has reduced its dependency on groundwater sources to some extent and has a future plan to establish a further three SWTPs with total production capacity of 1400 MLD within 2025. Sayedabad surface water treatments in khilket are MLD increases in rapidly which belongs to the year of 2015 to 2030. But still this is not good enough to meet the future water demand of Dhaka city. In Table 4 a projection shows that by the year 2030, if DWASA establishes another two SWTPs with total capacity of 1000 MLD to increase the supply capacity; the supply gap will be 1576 MLD. So it is inevitable to search for an alternative water supply source. So these are actually assumed that all of Dhaka city people are demanding their all concern about water protection road map to meet future demand. So these are the vital for all Dhaka city people.Because this is the capital city all of the people. In Bangladeshi people most of them wanted to be a urban citizen.

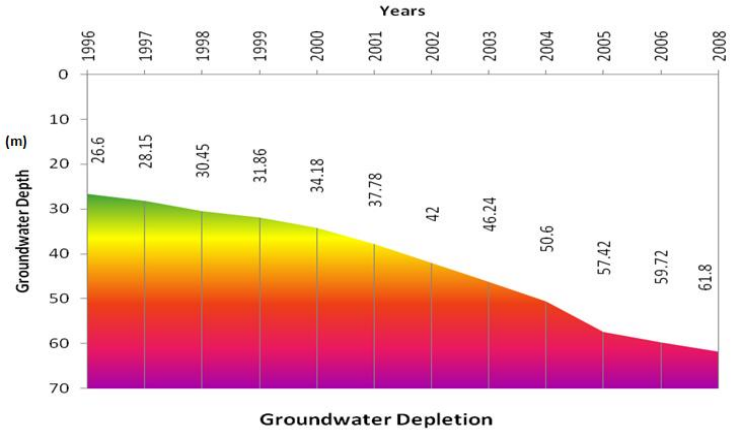

Fig. 1. Groundwater depletion of Dhaka city (1996-2008)
Source: [6] Mortuza, 2011

Table 2. Water supply data of Dhaka City (1963-2012)

Year	Supply (MLD)	DTWs	Large scale SWTP
1963	130	30	
1970	180	47	
1980	300	87	
1990	510	140	
1996	810	216	
2000	1130	308	
2001	1220	336	
2002	1550	394	
2004	1662	382	1
2005	1685	423	1
2011	2110	603	1
2012	2420	632	2

Source: [7] UnnayanOnneshan, 2011; DWASA, 2011 and The Daily Star, 2012

Table 3. Future water demand of Dhaka city

Year	Population (millions)	Demand (MLD)
2000	9.5	1425
2011	15	2250
2012	15.63	2344.5
2015	17.7	2655
2020	21.7	3255
2025	26.7	4005
2030	32.8	4920

Source: [8] City Population, 2013 and Author's Calculation

Table 4. Water production road map to meet future demand

	Year				
	2012	**2015**	**2020**	**2025**	**2030**
Total demand (MLD)	2344.5	2655	3255	4005	4920
UFW (%)	30	30	30	30	30
GW (MLD)	1970	1970	1970	1970	1970
Sayedabad SWTP I (MLD)	**225**	**225**	**225**	**225**	**225**
Sayedabad SWTP II (MLD)	**225**	**225**	**225**	**225**	**225**
SWTP III (Khilkhet) (MLD)		**500**	**500**	**500**	**500**
SWTP IV (Padma-Jasholdi) (MLD)			**450**	**450**	**450**
SWTP V (Sayedabad) (MLD)				**450**	**450**
Total Production Capacity (MLD)	2420	2920	3370	3820	4820
Actual Supply (MLD) (Total Production Capacity – 30% UFW)	1694	2044	2244	2859	3474
Total Gap (Actual Supply – Total Demand)	- 650.5	- 611	- 896	- 1331	-1576

Source: [9] The Daily Star, 2013 and Author's Calculation

3.6 Potentiality of Rainwater Harvesting in the Study Area

Rainwater harvesting potential equation calculates the potential of rainwater harvesting in DNCC ward number 3 by using three types of data - mean annual rainfall, area of catchment and run-off coefficient. A total of 390.9 ML rainwater can be captured from the rooftops of residential apartments. Table 5 shows that rainwater harvesting can meet about 20% of daily water demand of this area.

3.7 Test of Rainwater Quality

Quality test results of harvested rainwater stored in a Ferro cement tank for 4 months, tested in the Environmental Engineering Laboratory, Department of Civil Engineering, BUET (from September to December, 2005) shows that rainwater contains excessive amount of total coliforms which is hazardous for human health and also lacks of needed amount of nitrate and fluoride which are essential to be present in potable water [10]. So it is suggested to use rainwater only for non-potable purposes.

Using rainwater for non-potable purposes like toilet flushing and cleaning the house, 30 percent water can be saved from conventional piped water supply system. If total water consumption is 1, 10,000 litres per month in a building then

Water use in Toilet flush = 1,10,000*22% litre

= 24,200 litre per month

Water use in Cleaning purpose = 1,10,000*8%

= 8,800 litre per month

Total water consumption for these two purpose = (24,200+8,800) = 33,000 litres per month

Total population of the study area is 36,587. So, total demand of water per year for toilet flushing and cleaning purposes of the study area is 40*36,587*365 = 534,170, 200 litres per year or 5,34,170 cubic metre per year. So, rainwater harvesting will definitely reduce the pressure on DWASA a nd also partially solve the water scarcity problem.

Table 5. Capacity of rainwater in the study area

Total population	Total water demand (MLD)	Mean annual rainfall (mm) R	Total rooftop area (m^2) A	Run –off coefficient Cr	Annual rainwater supply (ML) S = R*A*Cr	Daily potential rainwater supply (MLD)
36587	5.5	2550	180350	0.85	390.9	1.1

Source: Author's Calculation

Table 6. Rainwater quality

Variable	Accepted range (WHO)	1st Sample	2nd Sample	3rd Sample	4th Sample	5th Sample	6th Sample	7th Sample	8th Sample
Total Solids (Suspended solids), m/l	10	15	10	6	6	6	6	7	7
Total Dissolved Solids, m/l	1000	80	80	75	68	72	75	78	78
Turbidity, NTU	10	0.83	0.82	0.82	0.80	0.82	0.81	0.82	0.82
Hardness as $CaCO_3$, m/l	200-500	16	18	15	17	15	15	16	16
pH	6.5-8.5	6.8	6.9	6.9	6.9	6.8	6.8	6.8	6.8
Nitrate, m/l	10	0.2	0.22	0.23	0.22	0.2	0.2	0.21	0.2
Fluoride, m/l	1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Lead, m/l	0.05	0.032	0.028	0.028	0.029	0.027	0.029	0.03	0.03
COD, m/l	4	1.5	1.5	2	2	2	2	2	2
BOD, m/l	0.2	0.05	0.05	0.05	0.045	0.05	0.052	0.05	0.05
Total Coliform, N/100ml	0	0	0	0	0	0	8	9	11

Source: [10] Islam, 2006

Table 7. Water requirement for different purposes

Use	Consumption (litres/day/person)	Percentage consumption
Drinking	5 litres	3.70%
Cooking	5 litres	3.70%
Bathing (including ablution)	55 litres	40.74%
Washing clothes	20 litres	14.81%
Washing utensils	10 litres	7.41%
Cleaning the house	10 litres	7.41%
Flushing of latrines	30 litres	22.22%
Total for urban areas	135 litres/person/day	100.00%

Source: [11] Centre for Science and Environment, 2010

4. CONCLUSION

Dhaka city is now facing tremendous challenge in fulfilling demand of water of the inhabitants of the city. The ground water is getting low day-by-day. The city dwellers are suffering because of inadequate water supply although the population or the demand is increasing. The city is now losing its river, khal and other water bodies. Recently rainwater harvesting has achieved great attention in urban areas like Dhaka city to reduce various water related problems such as water scarcity, water logging etc. Government has already taken some initiatives to promote rainwater harvesting not only in institutional building but also in residential buildings of Dhaka city. This study explores the potentials of rainwater harvesting for non-potable uses which can make a difference.

ACKNOWLEDGEMENT

We are immensely grateful to all the reviewers for their comments on an earlier version of the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Seraj TM, Islam MA, Mahid Y. Potentiality of rainwater harvesting as a source of rainwater supply system. World Town Planning Day 2012 BIP Souvenir. 2012;9-18.
2. The Daily Star.
Available:http://archive.thedailystar.net/newDesign/news-details.php?nid=260993
(Accessed March 3, 2013)
3. DWASA. Dhaka water supply and sewerage authority: Performance and challenges. Dhaka: Dhaka Water Supply and Sewerage Authority; 2011.
4. DNCC. Dhaka North supply City Corporation; 2013.
5. BBS. Population and Housing Census. Dhaka: Bangladesh Bureau of Statistics; 2011. BBS. Population and Housing Census. Dhaka: Bangladesh Bureau of Statistics; 2013.
6. Mortuza MR. Potentiality of rainwater harvesting in Dhaka: A greener approach. International Conference on Environmental Technology and Construction Engineering for Sustainable Development. Sylhet: SUST, 2011;5.
7. Unnayan Onneshan Water Supply of Dhaka City: Murky Future. Dhaka: Unnayan Onneshan; 2011.
8. City Population; 2012
Available:http://www.citypopulation.de/php/bangladesh-dhaka.php
(Retrieved March 14, 2013)
9. The Daily Star.
Available:http://archive.thedailystar.net/newDesign/news-details.php?nid=260993
(Accessed March 3, 2013)
10. Islam MM. University of Hawai'i - College of Tropical Agriculture and Human Resources; 2006.
Available:http://www.ctahr.hawaii.edu/hawaiirain/Library/papers/Islam_Manzurul.pdf
(Accessed January 16, 2013)
11. Centre for Science and Environment .A Water Harvesting Manual for Urban Areas: Case Studies from Delhi .Centre for Science and Environment, New Delhi, India; 2010.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/18760