Assimilating urban rainwater harvesting as fire extinguisher: A study in Dhaka city

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Abstract

Dhaka city is the capital of Bangladesh and the hub of all economic activities of the country. Most of the calamities that confront the city, *fire hazard* is the most vital one. In comparison with other cities of the country, Dhaka has the highest number of fire hazards which lead to a great number of losses in lives and damage to the properties every year. The traffic jam and scarcity of water during a fire mishap create the situation much worse together with the flaws of the roadway network and no water hydrant installed within the town. The rainwater harvesting system is currently the most efficient and sustainable way to acquire water from a roof catchment as the city is blessed with an enormous quantity of rainwater during the monsoon period, having an amount of 2148 millimeters (mm) in a year. The current study was to assess the potential of harvestable rainwater that can be accumulated through the urban rainwater harvesting system in a residential building, and by storing this harvested rainwater as *fire reserve* which can be used through a sprinkler system during a fire hazard. For a *Light Hazard- I* building type, the study revealed that only 55.70% of harvested rainwater needs to be reserved as fire reserve. The rainwater treating as fire reserve was assessed to be a sustainable and economical manner of exploitation through a fire sprinkler system, a simple extension of an already established technique.

Keywords— Rainwater harvesting system, Fire hazard, Fire reserve, Fire sprinkler system.

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1 INTRODUCTION

FIRE is one of the earliest innovation of civilization and an essential part of our existence on the planet. But due to its destructive nature, it is also the name of a dreaded demon which burns everything in to ashes when it gets out of control [15]. The term *fire* represents the process of uncontrolled combustion which endangers health and lives of people, material goods, and the environment [9].

Bangladesh is one of the most disaster-prone countries in the world. The country experienced several massive natural and human induced disasters among which fire hazard is the crucial one [20], [14]. Only in Dhaka city, fire hazards occur more frequently and cause a great number of losses in lives and properties each year [20], [27]. Dhaka city being the hub of all economic activities compels its residents to stay and construct high rise buildings, semi structured buildings and temporary shades in slums and squatters, readymade garment (RMG) factories and industries, educational institutes, medical facilities, and so forth. But these factors ignite the fire hazard incidents in a manner that it has now become a common phenomenon for the city [20].

The number of fire mishaps and economic loss due to it, is very high in Dhaka city in comparison with other cities of Bangladesh (see Table 1). Due to the rapid growth in urbanization, the residential and commercial fire in Dhaka has alarmingly increased along with the industrial fire. In 2007, there were 302 residential, 306 commercial and 129 industrial fire accidents in Dhaka alone [16]. The causes behind these fire hazards are chiefly of (most importantly) electric short circuit [15], lacking in regulatory framework, and the capacity of authorities to oversee and ensure safety even in the most hazardous areas of the city [10]. Only the electric faults are the cause of some 75% of fire accidents in the RMG sector [10] and on average 47 fire hazard accidents occur each year in the slum areas of Dhaka [20].

Studies reveal that fire stations located at Dhaka city is not capable of covering approximately half of its population and the fire fighting vehicles are not adequate for the extinguishing operation as per the requirements of a specific station coverage area [27]. The most important challenges in the firefighting operation include traffic congestion with deficiencies in the roadway network [16], [26] and scarcity of water. Due to the fast development, the natural reservoirs of the city are filled up and availability of water is the main issue during a fire hazard as there is no water hydrant installed in the city [16], [13].

Table 1: Year wise (2014–2018) fire accidents in the major cities of Bangladesh and economic loss in Dhaka city. Conversion rate: 1 USD = 84.50 BDT [29].

	Dhaka	Rangpur	Sylhet	Barisal	Khulna	Rajshahi	Chittagong	Bangladesh (total fire accidents)	Economic Loss (only in Dhaka)
2014	5,392	3,197	603	696	2,876	2,372	2,694	17,830	**178,02,86,190 BDT**
2015	5,752	3,329	724	739	2,313	1,977	2,654	17,488	**670,20,14,887 BDT**
2016	5,595	3,433	637	680	2,062	2,235	2,216	16,858	**129,42,93,612 BDT**
2017	5,066	3,208	619	789	2,357	2,286	2,471	18,105	**91,96,76,622 BDT**
2018	6,208	3,401	668	836	2,223	2,282	2,614	19,642	**166,86,32,410 BDT**

Source: [2].

Historically, rain-water harvesting system (RWHS) is used as a mean for potable water, irrigation and livestock supply, artificial groundwater recharge, and to reduce runoff and water logging problem during monsoon [19]. The potential of RWHS in Dhaka city fulfills all the criteria to be economically efficient, sustainable, and equitable source of water [28], [25], [18], [17]. The present study was to assess the potential of using this rainwater, harvestable from a residential building, and by keeping it as a *fire reserve* of which a sprinkler system can draw that water and operate during a fire mishap.

2 Sprinkler System

Sprinkler system is defined as a fire suppression or control device that operates automatically when its heat activated element is heated to its thermal ratings or above, allowing water to discharge over a specified area [21]. Records of fires in buildings with supervised automatic fire sprinkler systems have indicated successful extinguishment in more than 99% of fire incidents while the total amount of water needed for fire suppression is small (often less than 50 gallons per minute or 227.30 liters per minute). The total amounts of water used in sprinklered buildings approximately one-tenth the amounts used for fires in non-sprinklered buildings [8]. Design of sprinkler systems has three parts [7]:

- determination of water volume needed;
- the design of sprinkler distribution; and
- the design of the storage and pumping system necessary for the sprinkler operation.

Figure 1: Sprinkler head of a fire sprinkler system [21].

3 Volume of Water Required as Fire Reserve for A Building in Dhaka City

The requirements of the fire control sprinkler system design are dictated by various building codes [7]. In Bangladesh, *Bangladesh National Building Code* commonly known as *BNBC*, is the standard for design and code approval for engineering applications.

The volume of water needed for fire protection depends on building or occupancy type, hazard classification, water flow duration, design area, water density and type of sprinkler system [7].

For a *Light Hazard-I* occupancy or building type, the design area is 200 sq. meters (m^2). The design density is 1 liter per minute per sq. meter ($L/min/m^2$), which is the required volume of water to serve over the design area. The flow duration is 30 minutes (mins) for a building height upto 51 meters (m). The water volume needed for the sprinkler to operate is 1,000 liters/min (see Table 2).

So, required volume of water to be reserved as fire reserve and to operate through the sprinkler system is, (200 m^2 * 1 $L/min/m^2$ + 1000 L/min) * 30 min = 36,000 liters.

This amount of water is required for the sprinkler system to operate in an occupancy type, Light Hazard-I. This volume of water is in addition to the volume of water required for the potable and non-potable use by the building users. Also, this amount of water can be separated from the domestic water reserve and place at bottom of the cistern designated as *fire reserve,* and by providing a *fire pump,* this water can easily be drawn out from the reservoir and pumped to the sprinkler system, and distributed thereby.

Table 2: Water supply requirements for a fire sprinkler system to operate for different occupancy types.

Building Type	Sprinkler System (liter/min)*	Duration in minute for building height (upto 51m)	Design Area (m^2)	Calculated Design Density ($L/min/m^2$)
Light Hazard-I	1000	30	200	1.00
Light Hazard-II	1900	50	200	1.90
Ordinary Hazard-I	2650	75	130	2.65
Ordinary Hazard-II	3200	75	130	3.20
Ordinary Hazard-III	4800	75	130	4.80

* Values will be for one riser serving floor area of 1000 m^2

Source: modified after [4].

4 Study Area

The residential building chosen as the study location is situated at Shahjadpur area under the Gulshan P.O.-1212 of Dhaka city. It is a ten storied fully residential building having a latitude of 23°47′25′′North (N) and longitude of 90°25′36′′East (E). The total building height is above 33 m and a roof surface area of 4850 ft^2 (= 451 m^2). According to the [4], the building must comprise to have its own fire protection system (including a fire sprinkler system).

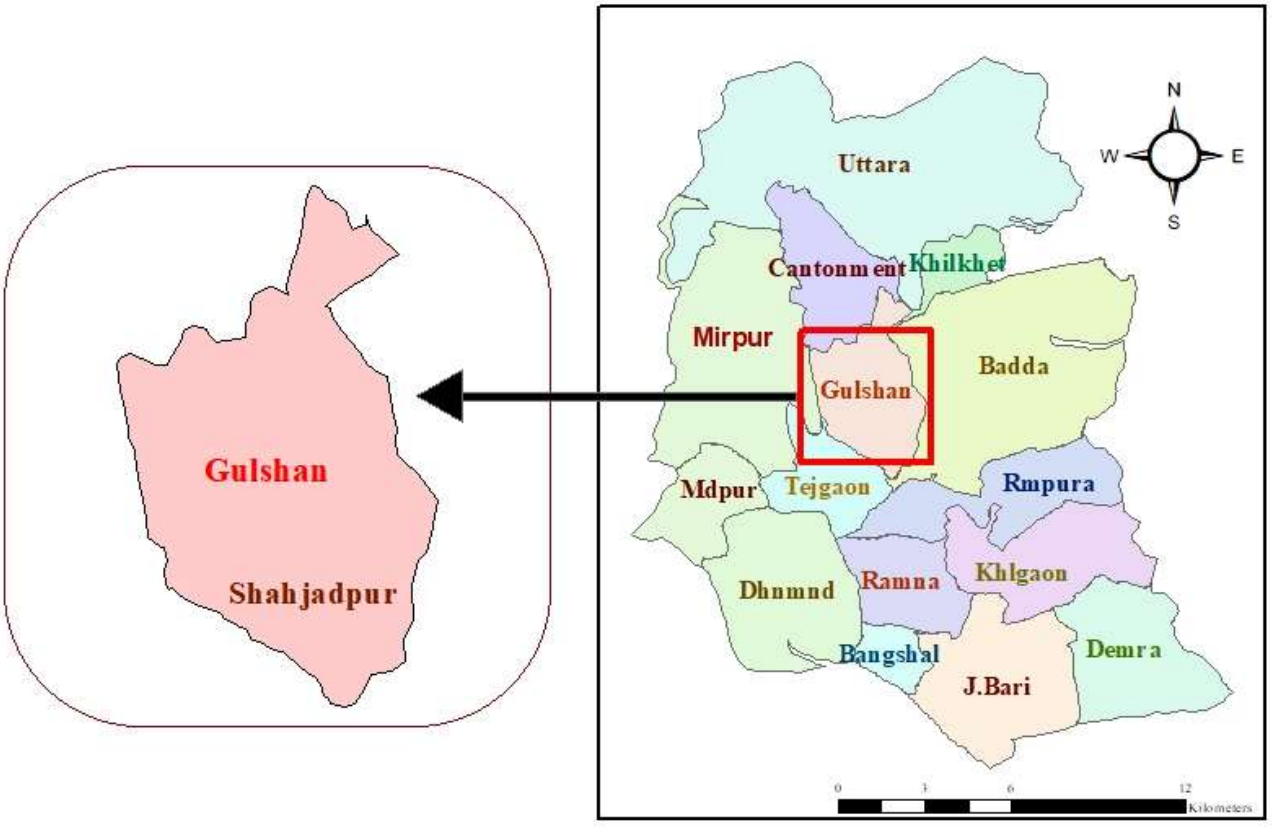

Figure 2: Map of Dhaka city with specifying the study area.

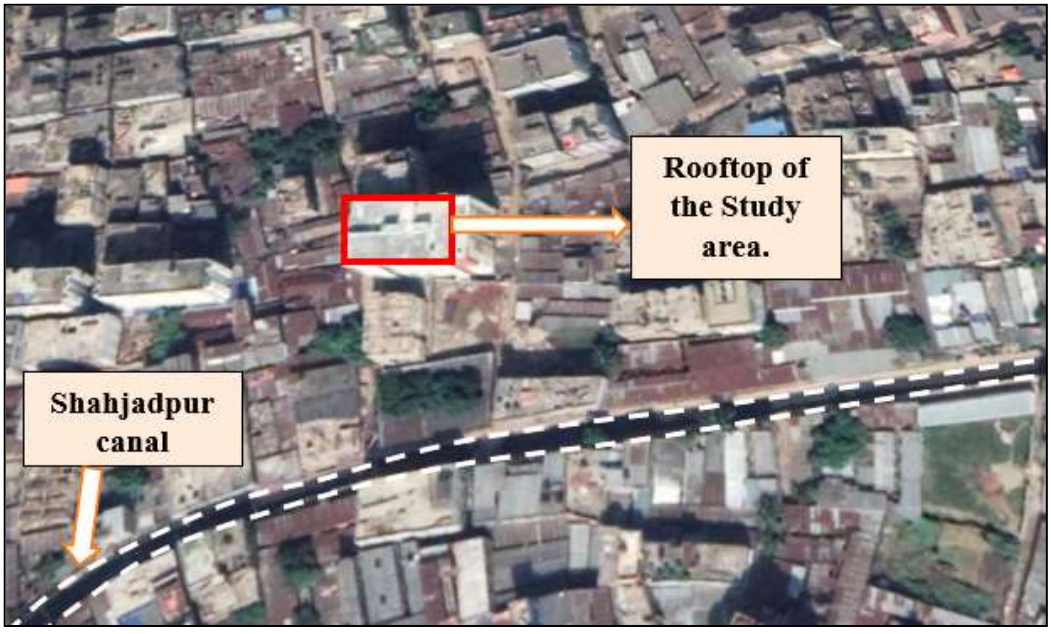

Figure 3: Aerial view of the study area. A 10 storied building with more than 33 meters in height which should be comprised of a fire sprinkler system in accordance with the building code.

5 Amount of Harvestable Rainwater from The Study Area

RWHS is a more effective technology that can be easily undertaken through three basic components: roof catchment, supporting collection system (gutter, screen/roof washer, downspout pipe, and flushing system) and storage tank [25], [1].

The maximum amount of rainwater that can be encountered from a rooftop is calculated by the following equation,

$$V = A * R * f \tag{1}$$

where V is the amount of harvestable rainwater, A is the roof catchment area, R is the total amount of rainfall and f is the runoff coefficient [25], [11].

The roof runoff coefficient f, which is the ratio between the amount of rainwater received from a rain event and the actual rainwater delivered via the gutters and down pipes, varies significantly based on roof material, slope of roof, etc. A value of f = 0.80 is typically used for Dhaka city [11].

Dhaka is located in a hot and humid country, and its annual temperature is 25°C, categorizes the city as monsoon climate zone. The city is blessed with a considerable amount of rainfall during the monsoon period- May to September [25].

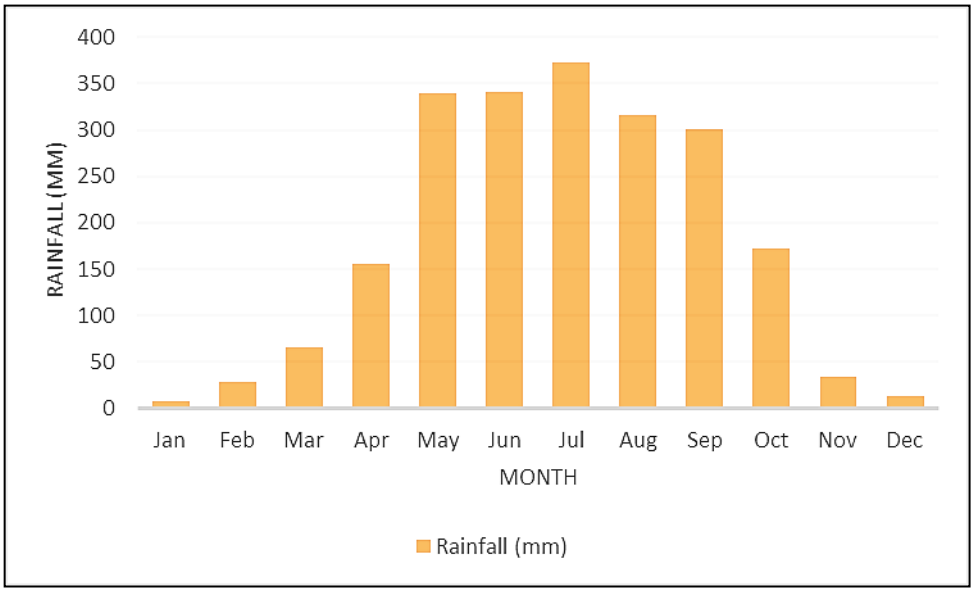

Figure 4: Average monthly rainfall (in mm) of Dhaka city [3].

In this study, average monthly rainfall from January to December (see Figure 4) was considered (including Dry and Wet period), so the average yearly rainfall, R is 2,148 mm, A is 451 m^2 and f is 0.80.
Therefore, from (1), the total harvestable rainwater from this roof surface is, V= 775.30 m^3/year = 775,300 liters/year. Then the amount of water that can be harvested from the roof surface of the study area in a month is approximately 64,608 liters.

6 Discussion

6.1 Proposed fire protection reserve diagram

The amount of rainwater that can be harvestable from this selected study location is found to be about 64,608 liters/month whereas the required water volume for a fire sprinkler to operate during the suppression of fire hazard is only 36,000 liters (for Light Hazard-I occupancy type). Only 55.70% of harvested rainwater needs to be reserved as fire reserve, and this amount of water can easily be acquired by adopting rainwater harvesting system. A self-sustaining system that can be developed, and, use without any intervention and any reliance only on the municipal water supply during a fire hazard. The following Figure 5 represents the design of a fire reserve by integrating RWHS and providing tank piping network for fire sprinklers to operate within a residential building.

6.2 Quality of rainwater

Rainwater quality is an important issue for its use in potable purpose [25]. Harvested rainwater did not always meet the standards due to its unprotected collection [25], [5]- [6], [12].
Haque and Rinkey [19] collected rainwater of different roof surfaces from seven different locations of Dhaka city and assessed the quality of collected water in terms of physiochemical tests like- Turbidity, pH, Electric Conductivity (EC), Total dissolved solids (TDS), Nitrate, Nitrite, Sulfate, Chloride and Fluoride. They concluded based on their test results that, harvested rainwater use in potable purposes were undesirable and unsafe for Dhaka city prior to any treatment.
The fire reserve water is kept well below the domestic water reserve, and fire pump needs to draw this water down from the reserve and distribute through the sprinkler system. So the quality of rainwater treating as fire reserve is a major concern and it should be well maintained [7]. To ensure a good quality of this water, local treatment can make the harvested rainwater potable [25] or use of sodium hypochlorite solution with the harvested water would enhance the quality [1], [24].

7 Concluding Remarks

RWHS may function as a major alternative or supplementary source of water which can be utilized in response to severe drought, increased water demands, public awareness of the environmental impacts of stormwater runoff [17], [30] and in this case for fire protection.
Within a time period of one-month, recent tragic fire accidents of Shaheed Suhrawardy Medical College (14 Feb 2019), Chawkbazar (20 Feb 2019), FR Tower (28 Mar 2019) and Dhaka North City Corporation (DNCC) Market (30 Mar 2019) has moved the city dwellers at a great deal. The constraints in suppressing these fire accidents were chiefly of scarcity of water and traffic jam, and therefore claimed the lives of 71 people in Chawkbazar tragedy [22], 26 people in FR Tower tragedy, and 200 shops burnt in the DNCC fire [23].
Rainwater harvesting for potable and non-potable use is commonly a sustainable and effective technique. By integrating this same technique for the fire sprinkler system is only a simple extension to the already established method. The availability of rainwater and potential of rainwater harvesting system implementation in Dhaka city, can be an effective way (as the study revealed) of protection from fire for the city residents along with saving losses of lives and properties during a fire hazard.

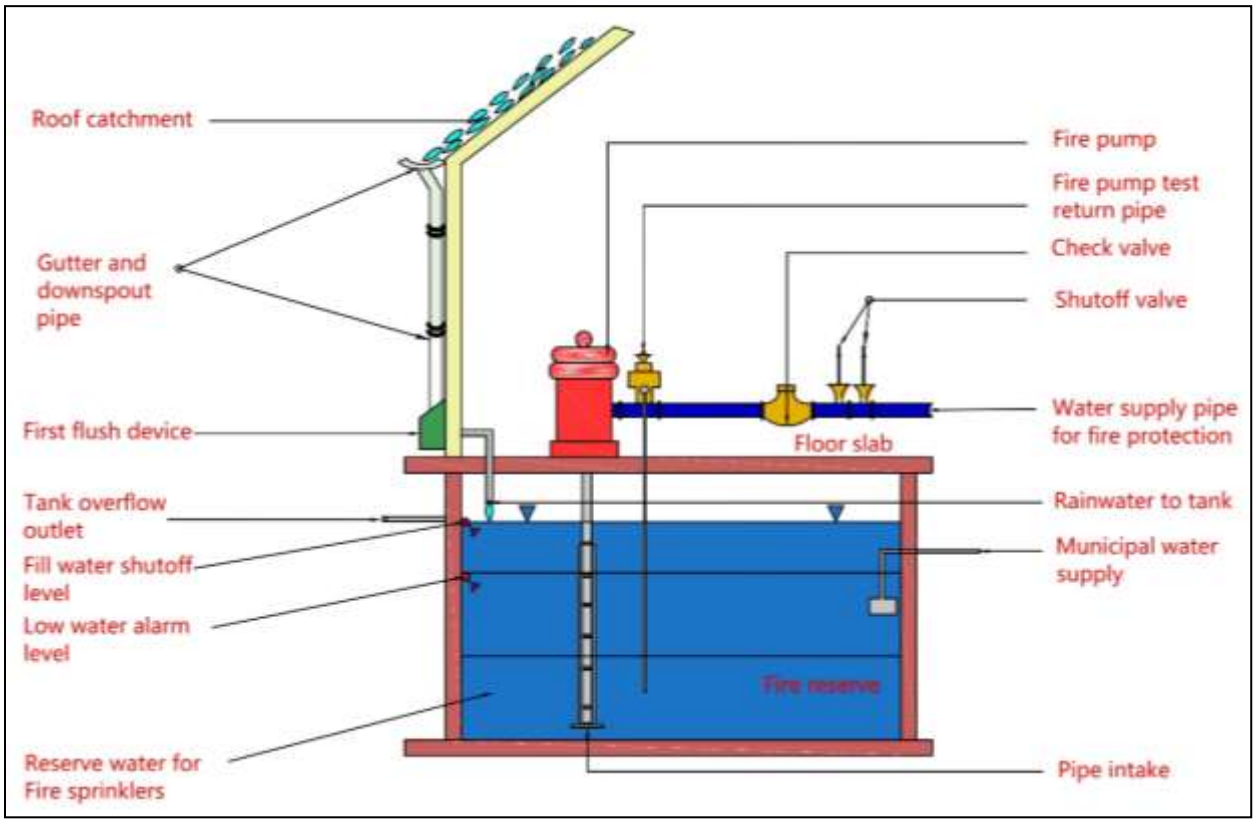

Figure 5: Water tank piping network by integrating RWHS and providing fire reserve allowance in a residential building (redrawn after [7]).

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