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Community Based Rainwater Harvesting in a Residential Area of Dhaka

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Abstract: During dry season, there is a serious deficiency of water supply in and around Dhaka city. The residents suffer a great extent during this period. On the other hand, during monsoon, there is abundance of water which is not used effectively and hence reaches the storm sewer system or a river. Rain water harvesting gives an opportunity to store rain water and to use the stored water later for different purposes. In Dhaka, 80% of the total supplied water comes from groundwater and remaining 20% comes from surface water. However, the population of Dhaka is increasing exponentially resulting in excessive pressure on ground water. The withdrawal of groundwater is taking place at a faster rate than recharge. The groundwater table in Dhaka city is declining at the rate of 3m annually. If this condition continues, very soon Dhaka city will face serious water crisis. In order to address this problem, in this study, rainwater harvesting has been looked into as a sustainable solution. More specifically, a community-based approach was considered. Aresidential community was considered for designing rainwater harvesting system. It was observed even though the harvested rainwater doesn't meet the full domestic demand but provides significant supplementary support during monsoon season. Community based rainwater harvesting also have the potential to decrease the seasonal flooding in the urban areas. It was observed that rainwater fulfil up to 39% of household water demand in this thesis building

Keywords: Water Supply, monsoon, storm sewer system, rain water harvesting, sustainable solution, household water

I.Introduction

Bangladesh has tropical monsoon with high rainfall from April to September (125 cm to 500 cm). The mean annual rainfall of Bangladesh is about 2320mm. The unique geographic location of Bangladesh, with the Indian Ocean to the south and Himalayas to the North, has made it one of the wettest countries of the world. Dhaka is the fastest growing mega city in the world. Every year the number of migrants is increasing in the Dhaka city. Urban sprawl exerts immense pressure on the infrastructures of the city. Twenty five percent of the total population has no direct access to potable water. Groundwater resource of the Dhaka mainly depends on the number of groundwater storage and the volume of annual recharge. In Dhaka city the depletion of the ground water table (GWT) has started from a depth of 100m. Some places one needs to dig 300m to reach the main aquifer. According to a study conducted by the Institute of Water Modelling (IWM), the groundwater level of Dhaka city is falling by 3m per year. In 2050 the GWT will go down to 120 m.

Dhaka Water Supply and Sewerage Authority (DWASA) has faced challenges due to unplanned city development. There exists some system loss in the collection and distribution process. DWASA is trying to reduce the scarcity of water but there is still some lacking in supply. Dhaka Water and Sewerage Administration (DWASA) has started using surface water to add to the groundwater supply, but it is still not sufficient. Considering the declining groundwater level of Dhaka city, it is obvious that other sources of water need to be explored. In many countries, rainwater is used to supplement water supply which is known as 'rainwater harvesting'. Rainwater harvesting process can be divided into three phases: collection, storage, and distribution. The first part of the rainwater requires some treatment before use. Rainwater harvesting has a high potential to become a supplementary source of household water supply. In this study rain water harvesting possibilities along with cost benefit analysis was explained in a residential area of Dhaka.

II. Rain Water Harvesting

There are many studies and experiments that have been done to establish the usage of rainwater. After increasing the awareness on water crisis, rainwater harvesting is to be proposed as a community facility. For example, United States have shown increasing interest in rainwater harvesting in small and medium residential and commercial constructions since 1996. Many cities and states are adopting the rules which are related to rainwater harvesting, especially in United States. Bangladesh is suffering from a major problem with groundwater contamination. Almost 50% of the country suffers from this problem. The average annual rainfall in Bangladesh is 95 inches (Chowdhury & Sultana, 2010). So, this amount of rainfall makes an obvious solution for the country. The annual rainfall in Dhaka city is about 100 inches and the ground water table is almost 65 feet below ground. Rainwater harvesting also facilitate some additional benefits to the consumers such as reduction in the scale of seasonal flooding, water logging and

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water hydrating. Community based rainwater harvesting (RWH) can be a better solution to reduce the water problem. Rainwater can supply a big portion of drinking water or other uses if properly monitored and supervised. A good RWH system can fulfil the demand and supply the water during need. There is a problem in RWH system that, it is one kind of burden for low-income people. Thus, different alternative method can be accommodated to reduce the overall loss of a "rainwater harvesting system".

III. Rain Water Harvesting System

Generally, a rainwater harvesting system consists of three basic elements. These are collection system, conveyance system and storage system. Among several RWH system pressurized system and gravity system are most popular. In pressurized RWH system, when the water is needed, the stored rain water is pumped at a normal pressure from the reservoir directly. A main water connection is added to the reservoir and act as an alternative when rainwater level in the tank is depleted. However, in gravity RWH system pressure the stored water is pumped from the reservoir to the elevated header tank when required. These services are fed by gravity; restore rainwater from reservoir only when the minimum level is reached. Buildings, with invulnerable rooftop are already in place, the catchments areas are effectively available and charge free and they should supply at the point of consumption. However, any kind of open areas, landscapes, park pavements or open field can harvest significant amount of rainwater.

IV. Types Of Rain Water Harvesting

Roof water collection and surface catchments are two main types of rainwater harvesting. In roof water collection system, the collection of rainwater is probably insignificant which is done by a simple household. However, the impact of thousands or even millions of household rainwater storage tank may play a vital role. Collected rainwater should be well treated before using or it can be filtered. In surface catchments collected water can meet the water demand during dry period, reserving the flows created by low-cost dams. There is a possibility of huge rate of water loss because of infiltration into the ground. The optimum quantity of collected water is the reason, and this technology is perfect for the agricultural purposes.

V. Components of Rwh

Important components of rainwater harvesting include catchment area, leaf screens and guttering, storage tanks and cisterns, filtration system and setting tank, first flush systems etc. Rainwater harvesting system depends on the availability of precipitation. So, the quantity of harvested rainwater depends on the intensity on rainwater and the size of the catchment area. For catchment area usually roof, courtyard and grounds are used. Among them the most developed practice for rainwater harvesting is roof. Rainwater can be collected from all kinds of roof except lead flashing or coated with lead-based paint. Leaf screen is the system to remove the contaminants and debris. Leaf screen is the system to remove the contaminants and derbies. To separate the first 2.5 mm of rain there has to be put a rain separator in place. Guttering is used as transport rainwater from rooftop to the storage vessel. The water storage tank represents the biggest amount of capital investment element in a domestic rainwater harvesting. There are huge numbers of options for storing water. In developing countries common vessels are used for small-scale water storage include, plastic bowls and buckets, jerry cans, clay or ceramic jars, cement jars, old oil drums, empty food containers etc. To store a large quantity of water, the system will require a tank or cistern. The size can vary from a cubic meter or above hundreds of cubic meters for larger project. For domestic system tank size can vary from 20 or 30 cubic meters. A German company, WISY, has developed a filter which fits into a vertical downpipe and act as both filter and first flush system. Normally they're used sand-charcoal-stone filter for filtering rainwater entering a tank. This type of filter is suitable for slow to moderate inflow.When rainfall starts debris, dirt, dust and droppings on the roof washed into the tank. This is the cause of contamination of water and the quality to be reduced. However, RWH system incorporates first flush device for diverting the first flush.

VI. Ground Water Recharge Technique

There are various methods for recharging ground water, including infiltration basins and canals, water traps, cutwaters, drainage wells for surface runoff and septic tank effluent, and diverting extra irrigation canal flow into sinkholes. Latin America and the Caribbean both employ these methods.Infiltration Basins and Canals are used in Argentina to recharge the San Juan River basin. It involves the construction of infiltration basins and infiltration canals. The high circulation velocities of the canals resisted the settling of fine material. This resulted in higher infiltration rates. Water traps are earthen dams of variable heights, normally 1m to 3m. The traps can be constructed of locally available materials. Water traps are designed up to 1in 50-year frequency and operate during rainfalls. Their storage capacity fluctuates between 250 to 400m^3.Cutwaters are reservoirs built on top of permeable strata and used for artificial recharge and surface water storage. Surface water harvesting is their primary objective. These kinds of technology are used in areas where there are no rivers or creeks to draw water from the earth. Drainage wells or "suck wells" can be used to dispose of drainage waters. The principal aquifer in Bangladesh comprises of lime stone and coral rock formation. The depth of the drainage wells depends on the well digger, that is based on fissure or 'suck' in the rock. The shape of the area is either

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square or circular and the range of area is 16 $ft^2$to 36 ft^2. The drainage ports or underground pipes or culverts are conducted with runoff in to the wells. In Jamaica, there is a limestone aquifer which treats the excess surface runoff and discharge in to sinkholes. Monitoring is helped to measure the changes in ground water levels and water quality, especially salinity level. The recharge water can be monitored through a series of monitoring and production wells.

VII. SELECTION OF STUDY AREA

MRT Line-06, Depot, CP-02 building project was selected as study area. In this project there are Fifty-four buildings & sheds and all the buildings are varied in height. In this study one of the buildings was considered for RWH. The total number of populations in this building is 150 (approximately). The Depot is situated in Uttara, Diabari Area.

Fig. 1 Satellite View of Depot, CP-02, MRT Line- 6

Fig. 2 Considered Building for RWH

A site visit was conducted to assess the condition of the building and identify the location for the storage and treatment tanks.

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Fig. 3 Measured Roof area of Building no. 32

VIII. Rainfall Water Demand in Project Area

A. Rainfall Data

The rainfall data of the Dhaka city for the year of 1991 to 2012 was collected from Bangladesh Meteorology Department (BMD). In the study area, there was no particular rain gauge station. Data from a representative location (recommended by BMD) was collected to estimate the rainwater volume.

B.Daily Water Consumption Data of Dhaka City

Dhaka is one of the fastest growing cities in the world. There are several studies focusing on daily demand of Dhaka City. One-third of the city dwellers receive only 40 l/p/d and they have to manage their daily activities with this little amount of water. On an average, 42.8 percent of the respondents can receive basic requirement of 50 l/p/d and the rest (57.8 percent) are suffering from water scarcity despite piped connection (Uddin &Batten, 2011). According to BNBC, the daily water consumption rate has estimated 135 l/p/d. This information was used in this study as it was well-organized and proved to be very useful for analysis.

C. Catchment Area Data

In this study, the basic catchment is the roof top of the building. Total area in this building is 229.5 sqm or 2469.42 sft. For this study, 21 years (1991-2012) of rainfall data was collected from Bangladesh Meteorological Department (BMD). The yearly rainfall distribution for the city of Dhaka from 1991 to 2012 is shown in Figure 4.

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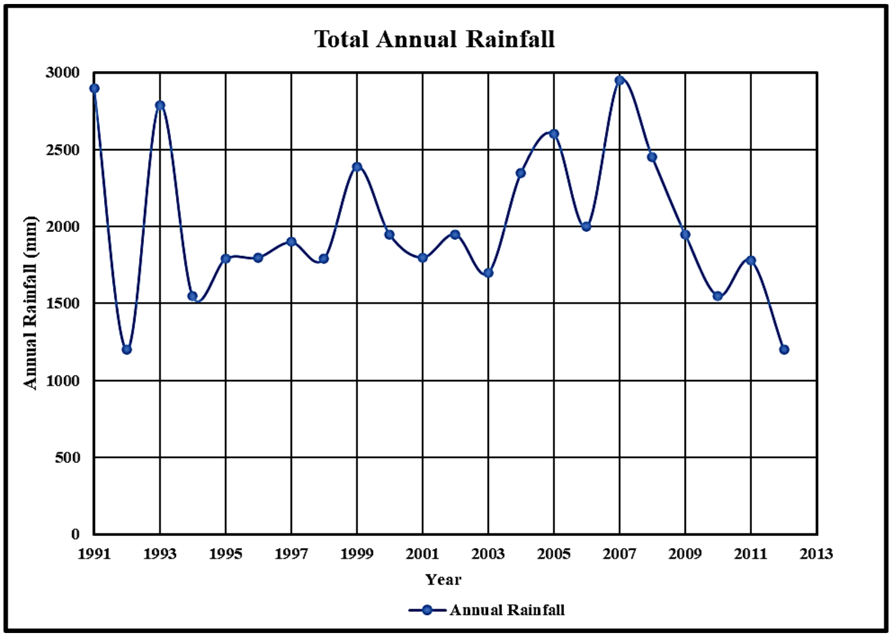

Fig. 4 Distribution of Annual Rainfall (over 21 years); Source: BMD (2014)

About 2800 mm rainfallwas recorded annually in 1991. The rainfall decreased near to 1100 mmin the next year which is also the lowest over the 21 years.Distribution of monthly rainfall is shown on the figure5.

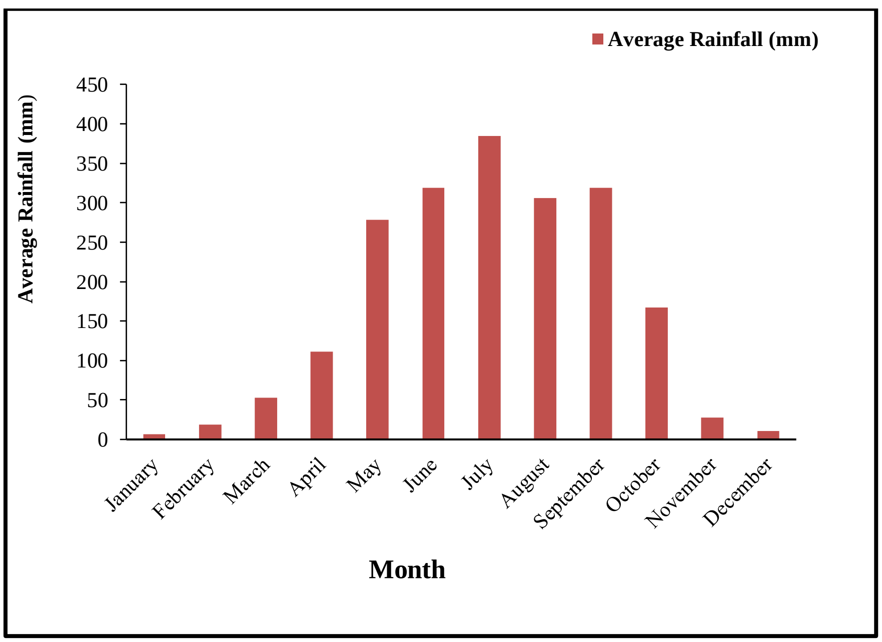

Fig 5: Distribution of Monthly Rainfall (over 21 year's average); Source: BMD (2014)

Maximum average rainfall was recorded in July (384.19 mm) where the minimum average rainfall was noted in January (6.91mm). It is evident that from April to October have more rainfall than other months. This is indicative of the monsoon season (April to October). Rainfall from these 7 months were taken into account when calculating the amount of rainwater that might be harvested. The percentage of rainwater that can be used to meet the water demand in a residential area has been determined by using these data. Figure6 shows the distribution of seasonal rainfall over 21 years.

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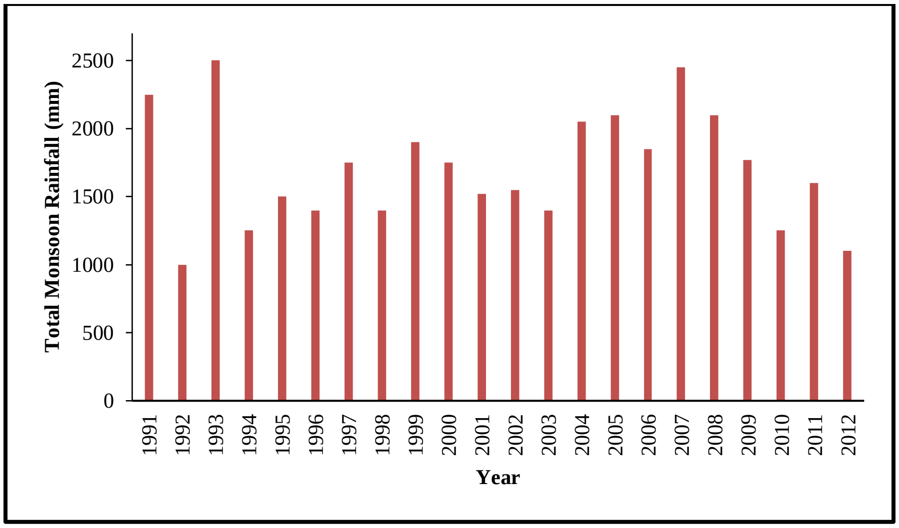

Fig. 6 Distribution of Monsoon Rainfall (over 21-year period); Source: BMD (2014)

From the graph it was observed that, the highest rainfall during monsoon season was 2500 mm, and the lowest was nearly 1000 mm. A significant source of water for rainwater harvesting is the additional water which is received during the monsoon. Water demand for the resident lives in the building is calculated from water requirement as per BNBC which is 135 lpcd. Table I represents the monthly water demand for residential area.

Table I: Monthly Water Demand for Residential Area

Number of Buildings	**1**
Number of Units	**15**
Number of family members in each unit (Approximately)	**5**
Other residents (security guard, staff, technician) (Approximately)	**8**
Water requirement for residential area as per BNBC	**135**
Number of Days in a month	**30**
Monthly Water Demand (liter)	**3,36,150**

D. Rainwater Harvesting Potential Calculation in Depot, Residential Building, B-32

Monthly average rainfall data is shown in figure 5 where maximum average rainfall (**R**) is found in the month of July which is 384.19 mm. The run off coefficient (**C**) of roof top area is considered as 0.85, which usually varies from 0.8 to 0.9. (IUB fact sheet, 2013). Volume is calculated using this formula: V= A×R×C, where A represents the total roof area which is 229.5m^2. By subtracting the first flush water volume of (roof area × First 2.5 mm rainfall) liter, total volume of collected rainwater is found 72923.27 liter which met 21.40 % of the water demand for the month of July.

E. Percentage of Water Demand Meet by RWH during Monsoon

In Table II it was observed that total roof yield during monsoon was 9,37,114 liter and the total monthly demand was 2,397,870 liter which satisfying 39% water demand for the residential area during monsoon.

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Table II: Percentage (%) Of Demand to Be Fulfil by Rwh for Residential Area

Month	Average monthly Rainfall (R)	Roof Yield (Liter)	Monthly Demand	% Demand Fulfils by RWH
April	0.111	21079	33,6150	6.27
May	0.278	52,793	34,7355	15.45
June	0.318	603,905.57	33,6150	18.28
July	0.384	72,923.27	34,7355	21.40
August	0.305	57,920.83	34,7355	16.96
September	0.318	60,389.59	33,6150	18.28
October	0.167	68102.75	34,7355	9.21

IX. Design of First Flush Tank and Sedimentation Tank

In Bangladesh the amount of dust is huge, especially in Dhaka. Therefore, in Bangladesh, the concept of discarding first 15 minute or 2.5 mm of rainfall as the first flush can be considered (Hasan et al, 2013). Some dimension and areas can be proposed by designing pipes and tanks to collect rain water.

By multiplying roof area 229.5 m^2 with 2.5 mm rainfall, amount of first flush water (small building) for the studied building was found 574 liters. "A one feet length of 3 inch inside diameter pipe holds approximately 0.74 gallons of rainwater (EFFD, 2003)". Therefore, the proposed volume of the first flush tank is 25 cubic feet.

Even after the first flush of rain, there may still be a significant amount of waste and debris. Sedimentation tanks are utilized to settle these wastes. However, for designing sedimentation tank rain water detention time was taken as 3 hours when surface over flow rate was taken as 0.5 m /hr, length to width ratio of the tank was considered as 3 and maximum flow rate of water was taken as 0.883 m^3/hr. Flow rate for this study area was found 0.10 m^3/hr. Therefore, amount of water treated by sedimentation tank at one time was found 4920 liters.

X. Treatment of Rainwater for Harvesting

Rainwater is generally of very high quality, but its quality can be negatively impacted in a number of ways through contact with air pollutants, and contact with contaminants present on roofs, driveways, and on the ground. Some treatment methods and maintenance measures are available which are: Primary Treatment, Secondary Treatment, RWH System Maintenance. Primary treatment includes screening out some of the larger debris (such as leaves or twigs) before they can enter the rainwater storage tank where secondary treatment is a treatment process for waste water to achieve a certain degree of effluent quality by using a sewage treatment plant with physical phase separation to remove settle able solids and a biological process to remove dissolved and suspended organic compounds. The principal part of improving the water quality is by performing regular maintenance of the RWH system. To reduce the entry of contaminants from the roof, the rooftop system should be inspected regularly, and any accumulated debris (leaves, twigs, etc.) should be cleaned out.

XI. Cost Benefit Analysis

Total cost per cubic feet for the sedimentation tank is 570 BDT [Mortuza M.R. et al, 2011], and the price of the first flush tank, a 700-liter plastic tank, is 5,200 BDT [Gazi Tanks, 2014]. The lengths of the main rainwater collection pipe, which has an 8-inch diameter, and the first flush collection pipe, which has a 1.5-inch diameter, are 125 feet and 105 feet, respectively. 8-inch diameter PVC pipe costs 285 BDT per running feet, 3-inch diameter PVC pipe costs 60 BDT per running foot, and 1.5-inch diameter PVC pipe costs 22 BDT per running foot, according to RFL-IS (2014). Table III shows the total cost and construction cost per family.

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TABLE III: CONSTRUCTION COST OF PIPES AND TANKS

Pipe and Tanks	Total Cost (BDT)	Total Cost (USD)
Sedimentation Tank	28044	254.39
First Flush Tank Cost (700-liter plastic tank)	5200	47.17
Total Cost of 8-inch diameter pipe	35,625	323.15
Total Cost of 3-inch diameter pipe	9000	81.64
Total Cost of 1.5-inch diameter pipe	2310	20.95
UV System (including UV lamp & other accessories) Cost	30,000	272.13
Total Filter (including filter chamber and filter bed) Cost	120,000	1088.52
Total	230,179	2087.95
Number of family	15	15
Construction Cost per family	15,345	139.19

XII. Pay Back Analysis for Residential Area

From table I it is observed that, monthly water demand in that building is 3,36,150 liters where RWH potential form rooftop during the month of July is 74334.8 litter, which is the highest during monsoon. Per unit (1000 litter) cost of water for residential area is 7.34 BDT [DWASA, 2014]. So, monthly water cost for residential area is 2467.34 BDT or 22.38$ and the amount save for RWH per month will be 545.62 BDT or 4.95$. So, the initial investment 15345 TK will be recovered in2.34 years.Finally, amount save per monsoon annually will be 3819.34 BDT or 34.64$. The average monthly income for a family in Bangladesh is 32,422 TK [Daily Star, 2022] and the initial investment is 15345 Tk which is almost half of it. But after the recovery of the initial investment, people will be benefited life time from it.

XIII. Qualitative Benefit Analysis

Use of rainwater for household purpose seems to be a viable and effective solution. Rainwater harvesting reduces pressure on the groundwater system. It also helps increase the groundwater level of our aquifer system, which is dangerously falling down on an average by 3m annually also from previous discussion it was observed that rainwater can fulfil up to 39% of household water demands during monsoon. The cost of a RWH system, might seem high compared to a conventional pipe system. However, if the installation and maintenance cost and add the cumulative saving of groundwater is considered, the long-term benefit overrides the cost of the system.

XIV. Conclusion

In this study, feasibility of a rainwater harvesting systems has been investigated for a residential community. Analysis has shown that rainwater harvesting enhances the water supply in Dhaka city. During monsoon, it provides safe drinking water, reduces the risk of urban flooding and reduces the scarcity of water during dry season. It also recharges the ground water table and takes pressure off from the overhead supply system. This study has also explained that rainwater harvesting is an energy efficient technology and can be a good solution for environmental sustainability. It also reduces the water bill for the dwellers of the Dhaka city. This study focused mainly on the community level RWH system. However, for some communities such as the slum

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dwellers, it is difficult to bear the cost of a RWH system. In such case, the government can take the initiative to introduce rainwater harvesting among the slum dwellers and provide them support for the maintenance of the system.

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