POTENTIAL OF RAINWATER HARVESTING IN BUILDINGS TO REDUCE OVER EXTRACTION OF GROUNDWATER IN URBAN AREAS OF BANGLADESH

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Abstract

Rainwater harvesting is an ancient technique which is very simple. In countries like Bangladesh, where annual rainfall is high, rainwater could meet a significant amount of total demand. Due to maladaptation to the paradigm of extraction of groundwater without considering the sustainability, people in Dhaka and other urban areas in Bangladesh are still reluctant to use this abundant source. This paradigm has been pushing the water supply scenario of Dhaka city closer to a condition where the city might face permanent water crisis, once the underground aquifers goes down below the pumping level or the aquifers become dry. Also the surface water condition of peripheral rivers of Dhaka city is in poor condition which does not encourage increasing use of surface water in Dhaka city. As an alternative of these options, rainwater harvesting has been considered though majority of the users are not fully aware of its potential to become a source of water. Analysis of the catchment availability and size of storage tanks are needed to find the potential of rainwater harvesting in the building and the capacity of buildings to store rainwater and use it. In this paper, an attempt was made to calculate the potential of rainwater harvesting in large and small premises of Dhaka city. Also the possible financial benefit from rainwater harvesting was also analyzed in this paper which would bring interest of the users.

Keywords: Rainwater harvesting, catchment, buildings

Introduction:

Rainwater harvesting is an ancient technique that has been practiced for thousands of years in different part of the world. It has been often found that areas where surface water or groundwater is not available in sufficient amount, rainwater harvesting is the best available option and popular also. In Bangladesh, rainwater harvesting is very much in practice in coastal areas where salinity has left only a few scarcely located ponds as a source of potable water. But in urban cities as well as municipalities, rainwater harvesting is still not a favored option as surface water and ground water are the main sources of water supply system. To carry with this current paradigm, sufficient reserve of good quality ground water and surface water in nearby water bodies is important. But it has been observed in recent past that many of the cities and municipalities in Bangladesh are running out of such sources that have good quality water, mainly during the dry period. Over extraction of groundwater to keep pace with the increasing demand of water and pollution of surface water through indiscriminate disposal of domestic and industrial waste has forced the water supply authorities in many places to think about new water sources for future. Dhaka, the capital of Bangladesh has been suffering water crisis for a few years. About 87% of its supplied water comes from ground water sources and 13% from peripheral rivers (Khan, 2012). But due to over extraction of ground water, the water table has gone below the pumping level which has resulted in abandoning deep tube wells at many locations. Also due to poor quality of peripheral river water, Dhaka Water Supply and Sewerage Authority (DWASA) cannot think of using these rivers as a potential source for future. In addition to this crisis, the population of Dhaka city is increasing day by day due to migration from rural areas which is putting more pressure on DWASA.

To address this crisis of water sources, rainwater harvesting has been thought as one of the potential alternatives in Bangladesh. Bangladesh has been blessed with huge amount of rainfall every year. A significant portion of the demand during rainy season could be met from this rainwater which would also reduce the pressure from city water supply. But the main challenge identified to use rainwater is the storage system. As people of Dhaka city are used to get water twice every day and the shortage of water source was not in vision of the authority as well as citizens, storing rainwater was not considered during planning and construction of the facilities. The willingness of people to store rainwater has not been found in favor of this potential alternative also (Tabassum, 2013). To overcome these barriers in order to promote rainwater harvesting in Dhaka, analyzing cases and understanding the probable impact of storing rainwater in reduction of groundwater extraction as well as cost reduction would be vital. In this study, an attempt was made to find out the potential of rainwater harvesting in large premises with high water demand as well as in few residential buildings with smaller catchment areas. Volume of water that can be harvested from available rainfall and subsequent reduction of water bill was analyzed in this study. It shows the potential of rainwater harvesting practice as an alternative in future years to address the looming water crisis in Dhaka.

Background:

Due to capital base centralization of Bangladesh, Dhaka has always been the center of development since independence. Lack of proper planning with urbanization and industrialization makes Dhaka city over populated with huge migration each year; polluted and ecologically imbalanced. Dhaka is the 19th mega city in the world and water crisis has become an acute problem in Dhaka city. Dhaka Water Supply and Sewerage Authority (DWASA), established in 1963, is a service oriented autonomous commercial organization in the Public sector, entrusted with the responsibility of providing water supply, sewerage disposal (wastewater), and storm water drainage services to the urban dwellers of this fast-growing metropolitan. It covers more than 360 sq. km service area with a production of almost 2110 million liters per day (MLD) against the present demand of 2250 MLD (Khan, 2012). It has been estimated that water demand in Dhaka with current rate will be 4990 MLD by 2030 (Paul, 2009). DWASA faces a number of challenges. These include unplanned city development and informal settlements, transitioning to using surface water instead of groundwater, and large investment funding (Khan, 2012). Most of the slum areas of this city do not have any legal water supply system.

According to ibid (2011), approximately 90% of the city’s water supply comes from ground water which is higher than the estimated 87% by DWASA. Institute of Water Modeling (IWM) and DWASA have projected that only 39.5% of city’s water demand would be fulfilled in the year around 2030 against the estimated demand of approximately 4990 million liter per day (ibid, 2011). It has also been estimated that groundwater sources would contribute about 87% out of that 39.5%.

However, according to various studies, the city's ground water table has been depleting at an alarming rate (Nahian et al, 2013). According to a study conducted by Institute of Water Modeling (Bangladesh), the city's groundwater level has been falling by 3 m/year, which now stands approximately 60 m down below the surface level compared to 10 m in 1970 (Biswas et al, 2010). In another study of Bangladesh Agricultural Development Corporation (BADC), the level has depleted down to 61.18 m below the surface in Dhaka city (ibid, 2010). Also due to severe electricity shortage and rising consumption charge, the option of groundwater extraction has become difficult and costly (The Sydney Morning Herald, 2010; Islam et al, 2010).

As the ground water table is lowering alarmingly, DWASA is attempting to shift towards surface water for new sources. But the water quality of the peripheral rivers of Dhaka city has been severely damaged in recent years due to municipal and industrial untreated wastewater that are discharged into these rivers (Kamal et al, 1999; Subramanian, 2004). In addition to that, the increased rate of urbanization and illegal encroachment has reduced the amount and volume of surface water bodies around Dhaka city (Seraj, 1994; Tawhid, 2004). Most of the small and large scale industries usually dump their wastes directly to the rivers without any treatment or with little treatment. At dry season, the existing treatment technology of Dhaka WASA cannot treat the raw water as per standards (Begum and Ahmmed, 2010). Currently there are three treatment plants working to treat river water in Dhaka. But due to the poor quality of river water, a pre-treatment plant with the existing treatment system was installed in 2012 by DWASA. This has led DWASA to go further upstream to find water of better quality though it would need huge investment as well as the complexity in water supply system would increase.

Considering the adaptive capability and available resources, rainwater harvesting has the potential to become a solution to water crisis in urban areas. In Bangladesh, where average rainfall varies from 1200 mm in the extreme west to over 5000 mm in northeast (WB, 2000), rainwater is considered to be the next option (Haq, 2005) to look into. Generally, urban areas are typically characterized by concentrated demand of water because of its high population density and varied uses of water. In urban perspective, rainwater harvesting appears in different perception than in rural perspective (Haq, 2013). Promotion of rainwater harvesting would face the challenge of unavailability of suitable structures for storing rainwater and should be analyzed in the context of financial benefit. In this paper, typical examples were studied where water consumption is high and also cases were studied for residential buildings to explore the feasibility of harvesting rainwater in the context of financial benefit and reservoir's capacity.

Methodology:

Rainfall is an unpredictable variable to calculate the potential of rainwater harvesting of an area. In this study, average monthly rainfall of 30 years (1980-2010) from Bangladesh Meteorological Department (BMD) was used. Normally water is stored in the underground tank of facilities and it is designed based on the daily demand of that facility. In this study, one Engineering University and four residential buildings (Mohammadpur, Banani, Jatrabari and Baridhara) were studied and its water consumption, storage capacity and potential catchment area were analyzed. Dhaka city has almost 45 private universities like Ahsanullah University of Science and Technology (AUST), with a large amount of consumption each day. Hence, rainwater harvesting in these buildings will reduce pressure on DWASA water supply. Moreover Dhaka city is highly occupied by high-rise buildings and daily consumption of these buildings are getting higher with better life style. Here two duplex buildings (Banani and Baridhara) and two multistoried buildings (Jatrabari and Mahammadpur) were studied that have relatively smaller catchment areas. Within Dhaka City Corporation (DCC) boundary area, 81% of buildings have less area than 2160 ft^2 or 200 m^2 (Tabassum, 2013). Therefore, the studied buildings would represent a large number of structures of Dhaka city which consumes a significant part of the total daily water supply.

The monthly water bills of all the studied buildings of last one year were collected. From this bills, which are prepared by DWASA based on the water meter reading, monthly water consumption was calculated. Along with that, number of users and their type of use was analyzed to get the theoretical water consumption per day based on the Bangladesh National Building Code (BNBC) guideline.

The rooftop of the buildings was considered as catchment. The total rooftop area was calculated from the design drawings of all the buildings. The rain that falls on this rooftop was considered for calculating the rainfall potential. Rain falling on ground was not considered as it often carries contamination. The capacity of underground storage tank was calculated during survey. The average rainfall was taken as monthly basis and monthly consumption of the buildings was compared to available monthly rainfall. The calculated probable supply of water from rainwater is based on the assumption that rainfall event will be evenly distributed throughout the month. But the analysis based on such assumption may not fully comply with actual scenario as the distribution of rainfall often varies and is not uniform.

Rainwater harvesting potential was measured by using the formula (A*R*C) where A is the catchment area in m^2, R is the average rainfall in mm and C is the runoff coefficient. For the rooftops of the studied buildings, C was assumed as 0.8 (Pacey et al, 1989). For calculation of water bills, at first monthly bill was divided by two (50% of bill is for sewerage system). Current water tariff in Dhaka was used to know the monthly consumption of water in thousand liters (Vat was considered). Based on the collected water consumption information, available rainfall, catchment and storage capacity, analyses were made to find the amount of money that could be saved approximately if rainwater was used to the buildings with existing reservoirs capacity.

Results and Discussion:

Ahsanullah University of Science & Technology houses about 6500 students, faculty members and staffs with a water consumption of about 1,306,467 liters per month on average. This huge amount of water is supplied from DWASA which is abstracted by deep tube well. The university complex has plain roof area of about 12,500 ft^2. The building has a rooftop area of 33,000 ft^2. It has underground reservoir of 405,000 L capacity and cumulative volume of its 5 overhead tanks is 598,590 L. Total annual rainwater harvesting potential from the rooftop is 5,788,613 L. The authority paid BDT 523,204 (50% of DWASA bill) for its water consumption in 12 months.

Among other four residential buildings, one has rooftop catchment of 5,040 ft^2 with an underground reservoir of 40,752 L capacity in Banani area. Monthly average water consumption of this building is 192,833 L and annual rainwater harvesting potential is 884,021 L. The residents of the building had to pay BDT 32,402 in one year for water bill. The building in Baridhara has catchment area of 4,320 ft^2 and the reservoir capacity is 36,377 L. Average monthly water consumption is about 193,083 L. Annual rainwater harvesting potential from this building is 757,732 L and its one year water bill was BDT 28,379. The building studied in Jatrabari has a rooftop catchment of 1,500 ft^2 and has underground reservoir of 32,600 L capacity. This has the smallest rooftop among the studied buildings. Average monthly water consumption by its residents is 183,444 L. Annual rainwater harvesting potential in this building is 263,093 L. The residents had to pay BDT 15,756 for water bill in one year. The last building is in Mohammadpur area with a rooftop catchment and reservoir capacity of 2,600 ft^2 and 32,600 L respectively. It has average monthly consumption of 630,333 L though annual rainwater harvesting potential is 456,046 L, which indicates that the density is higher in this building compared to other three residential buildings. The one year water bill for water consumption was found BDT 51,261 for this building.

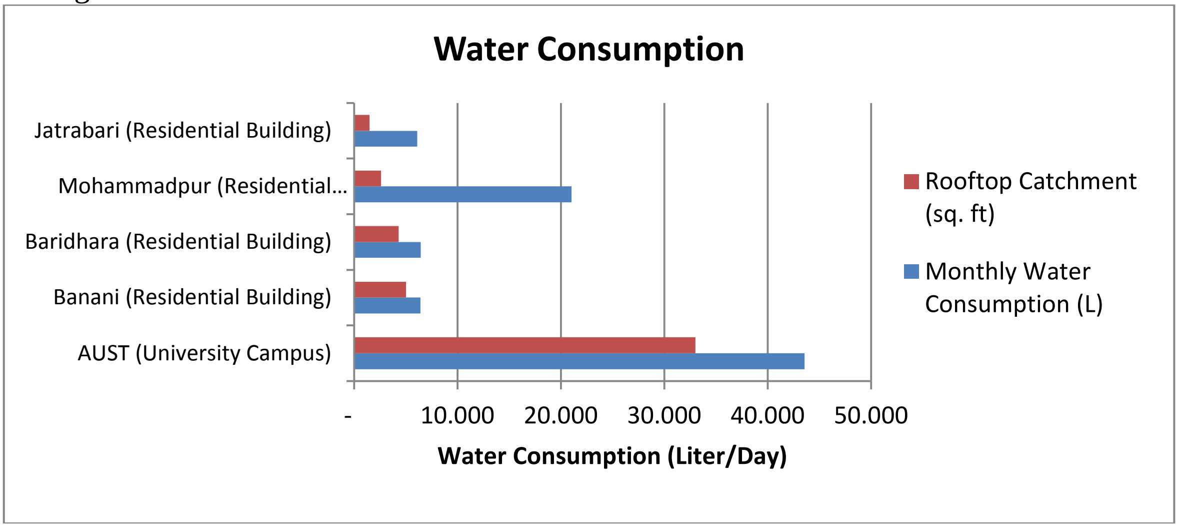

Figure 1: Water consumption of studied buildings and their rooftop catchment area

From figure 1, it can be observed that AUST has the highest water consumption which is due to its large number of users. In comparison, other buildings show less water consumption as they have fewer units. Among the four residential buildings, the one in Mohammadpur shows that its consumption is higher than other three though its catchment area is not big. Rainwater harvesting potential will be less in these types of buildings and the percentage of demand that can be fulfilled by rainwater will be less in these types of buildings which is shown in figure 2 and 3.

Figure 2 shows the amount of money that could be saved if rainwater was used in these buildings. It also shows that use of rainwater will be highest from June to September when rainfall is highest compared to other periods in Bangladesh. This would reduce the extraction of groundwater during this period. During the rainy season, the cumulative water balance after every rainfall event will decide how much water could be harvested. As the reservoir capacity is limited, often heavy rainfall event or persistent rainfall over a few days would cause wastage of rainwater. In that case, all rainwater could not be harvested. Figure 2 gives an idea about the scenario if large reservoirs could be built for storing rainwater of all the rainfall events. It will need to know the cumulative water balance after every month or a certain period to know the maximum size needs to be built for a reservoir.

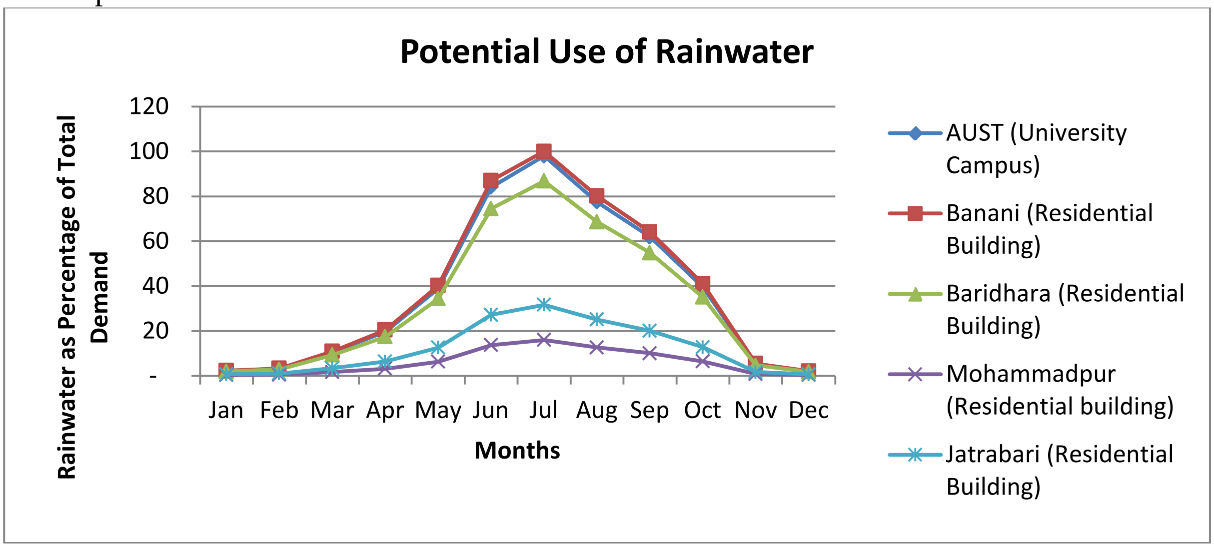

Figure 2: Percentage of demand that can be supplied by rainwater throughout the year

Figure 3 shows that if rainwater could be harvested to its full potential, a lot of money can be saved during rainy seasons. In buildings with comparatively larger catchment ratio to the number of users (AUST, Banani and Baridhara), it was observed that more than 60% of water bill can be saved during the period from May to October.

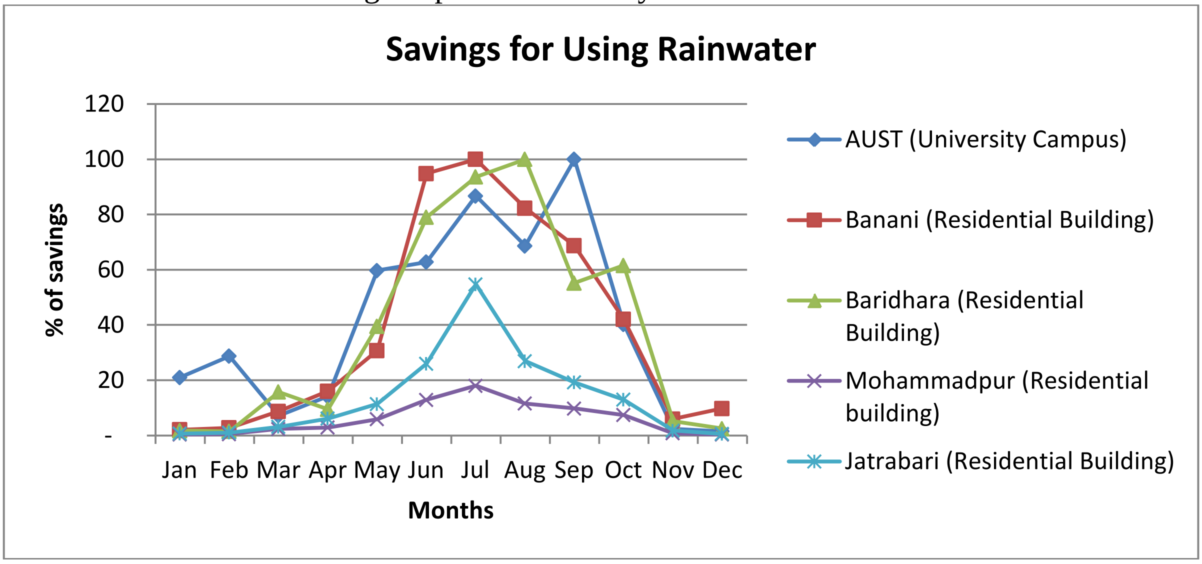

Figure 3: Percentage of water bill could be saved if rainwater harvesting was used to its full potential

Conclusion:

From this study, it can be said that rainwater harvesting could be very useful and acceptable solution as a low cost technique for the buildings. Ground water extraction will be decreased if we are able to use rainwater harvesting in households of Dhaka city where a reservoir tank of large volume exists. Large premises like AUST campus which consumes a huge amount of everyday which can reduce their dependence on DWASA by rainwater storage. Monthly cost for water consumption will be less by using rainwater harvesting in these buildings which would not take any significant investment also. Also the buildings and apartments should start practicing rainwater harvesting, at least to a certain percentage of their total demand. This would not only reduce their water bills, but also will reduce extraction of groundwater. For further development of the study, water quality test should be performed. Ensuring clean catchment area and storage facilities is the requirement for changing people's perception in favor of rainwater harvesting.

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