ASSESMENT OF ROOFTOP RAINWATER HARVESTING SYSTEM IN KHULNA CITY AND PROPOSAL FOR MODIFICATION

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ABSTRACT

Safe drinking water scarcity is the burning issue in the present situation of Bangladesh which needs to be addressed. This crisis has been further aggravated due to abuse of groundwater. Salinity intrusion in groundwater also added to this problem greatly. Due to the abusive pattern of withdrawal of groundwater without considering the sustainability, people in the Khulna city, are still reluctant to use the abundant resource of rainwater. In this situation rainwater harvesting (RWH) system can hold a great potential in dealing with the current challenges in future to meet the necessity of safe drinking water as well as other potential necessities. Around 1.5 million people live in Khulna city. Annual average rainfall in Khulna is approximately 1800 mm which can presumably meet the daily necessities of those people. This study focuses on the problems in existing rainwater harvesting (RWH) systems at Khulna city with special emphasis on perceptions about the reliabilities of RWH system among the users. Furthermore, this study probed into the possibilities of using a filtration unit attached with RWH system in order to elevate the water quality.

Keywords: *filtration unit, Khulna city, modification, rainwater harvesting system, water quality.*

1. INTRODUCTION

Rainwater harvesting is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered technologies. (Un-habitat, 2005). Rainwater harvesting is one of the most ancient process of collection of water that has been used in various part in the world. As pure drinking water crisis is one of the most important problems in recent world, rainwater harvesting can play an important role to remove this crisis. There is now increasing interest in the low cost alternatives known as "rainwater harvesting" (http://members.rediff.com/asitsahu/). As it is a very simple technique, a country like Bangladesh where the annual rainfall is very high (the average annual rainfall varies from a maximum of 5690 mm in the northeast to a minimum of 1110 mm in the west according to meet Bangladesh), the rainwater can meet the daily necessities for the people according to their demand. In Bangladesh this practice is seen mostly in the coastal areas where the groundwater is affected with too much salinity problem as well as arsenic. In those cities which have the facilities of municipal drinking water supply system, rainwater is not a favourable option for them. But it is a matter of great concern that the underground water level is decreasing day by day because of the abuse of water. It has also been seen that the municipal facilities are losing their potential good quality water sources especially in the dry season. Over withdrawal of groundwater and as well as pollution of surface water by disposal of domestic and industrial waste have forced the people to pay attention for thinking of alternate water supply system. In this sense rainwater harvesting system can be the solution. Rainwater harvesting system has already been introduced in many cities especially the coastal areas in Bangladesh. Khulna city is one of them. But a true fact is people don't have proper knowledge about the design of storage reservoir and so they are not getting the full benefit of this system. The RWH system requires careful considerations of the storage capacity of the tank as well as the collection process. Proper design is always needed to have a successful rainwater harvesting system. Moreover rainwater harvesting system ultimately depends on the total amount of precipitation, rainfall intensity and rainfall pattern. The average yearly rainfall in Bangladesh varies from 2200 to 2800 mm, 75% of which occur in May and September (Ahmed and Rahman, 2000). An increase of 4.26% was observed in the present difference between the total annual precipitation (average of 34 meteorological station data) of the past 20 years (1953-1972) and recent 20 years data (1985-2004) and that represents and increasing rate in the annual rainfall perspective (Rajib et al, 2011). According to IPCC, 2007 Bangladesh can undergo a 5-6% increase of rainfall by 2030.a project was taken by the Asian development bank named Bangladesh: Khulna water supply

project on 1 march 2011. They reported that people of Khulna city have been suffering from limited access to water supply services. They also reported that only 17% of the total population of Khulna city has the access to piped water supply and the rest resorts to alternate sources like tube wells and public taps. They further reported that the existing system is old and poorly maintained, resulting in poor quality of water, insufficient water and leakage. According to their survey they told that those houses which are connected with water supply network can enjoy proper supply of water only 5.3 hours per day and for about 59% of the surveyed household the quality of water is dirty and 55% of rate of the standard of service is very poor or poor. Now from those data analysis it can be easily said that a proper rainwater harvesting system can easily be the best available option for the future world. The study focuses on the problems in existing rainwater harvesting (RWH) systems at different places of Khulna city and to develop a modified rainwater harvesting system with and without filtration unit. It further focuses on the performance of the developed RWH systems.

2. STUDY AREA

Khulna is the third-largest city in Bangladesh. It is the administrative seat of Khulna District and Khulna Division. The city has a population of more than 1.4 million people. Khulna is an old river port located on the Rupsha River. It is an important hub of Bangladeshi industry and hosts many national companies. It is served by Port of Mongla, the second largest seaport in the country. Khulna is located in south-western Bangladesh at 22°49′0″N 89°33′0″E, on the banks of the Rupsha and Bhairab river. It covers a total area of 59.57 km² while the district itself is about 4394.46 km². It lies south of Jessore and Narail, East of Satkhira, West of Bagerhat and North of the Bay of Bengal. It is part of the largest delta in the world. In the southern part of the delta lies the Sundarban, the world's largest mangrove forest. The city of Khulna is in the northern part of the district, and is mainly an expansion of trade centers close to the Rupsha and Bhairab rivers. The Mayuri_River forms the western boundary of the metropolitan area. The survey area was a place in Khulna city named Natunbazar situated just at the bank of Rupsa river.

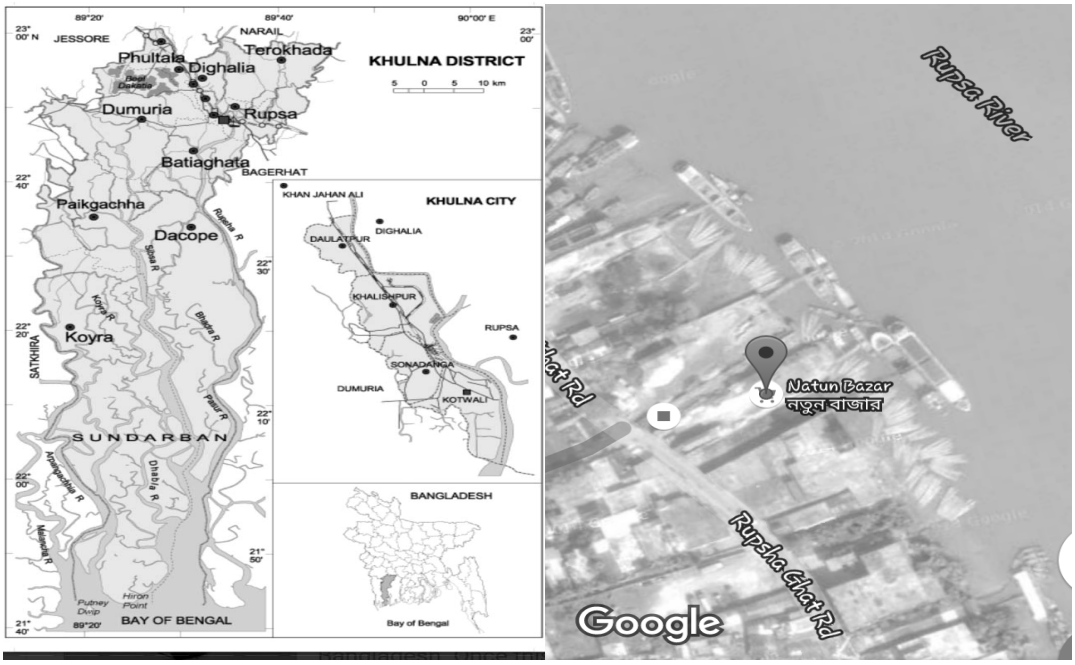

Figure 1: Map of Khulna City and surveyed area Natunbazar

3. METHODOLOGY

3.1 Data Collection

Both primary and secondary data were collected for the research purpose.

3.1.1 Collection of Primary Data

The study was performed at different places in Khulna city where rainwater harvesting system is already developed. Details field survey was done by visiting those places and by questionnaire survey among 30 families who were already using RWH system. Different questions were asked to those family members about their perspectives and problems towards RWH system. Various observations were also done during that survey whether those people use any filter media with their RWH system or not.

3.1.2 Collection of Secondary Data

The main objective and motto of this research is to propose a filtration media for the RWS system. The filtration media contains a large pot having 3 layers of stone inside it. The last 20 cm layer contains the big stones passing 1 inch sieve and retained on ¾ inch sieve. The middle 30 cm portion contains stones passing ¾ inch sieve and retained on ½ inch sieve. The upper 20 cm portion contains stones passing ½ inch sieve and retained $^3/_8$ on inch sieve. A tap was inserted in the end of the pot. The whole setup was installed in a safe and suitable place for collection and filtration of rainwater. Two types of sample were taken, one was directly collected from the roof and the other was collected through the filtration media. Then those samples were taken to the laboratory for analysis. The tests that were performed in laboratory were pH, Color, Turbidity, Alkalinity, Chlorine (cl^-), Total coliform, E.coli, BOD5, COD, Hardness and Nitrate + N_2.

4. RESULTS AND DISCUSSION

4.1 Monsoon Rainfall in Khulna City

The monsoon period belongs 5 months mainly in Bangladesh. They are June , July , August , September and October. The monthly rainfall data from 2005 to 2014 of all months were collected from Meteorological Department Bangladesh and listed below from which the amount of rainfall and its variation can be understood.

Table 1: Monthly rainfall data of Khulna city (Bangladesh Meteorological Department)

Month	**Monthly Rainfall (mm) from 2005 to 2015**										
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
January	15	0	0	66	1	0	0	66	1	0	41
February	0	0	54	36	6	2	1	18	7	24	35
March	148	5	14	48	10	14	16	1	19	5	28
April	43	19	92	36	23	21	28	52	62	0	107
May	215	230	119	151	130	146	145	63	430	118	128
June	102	262	374	190	233	287	381	255	212	447	***
July	435	522	591	301	347	180	387	391	313	394	***
August	194	364	160	202	568	205	614	254	482	258	***
September	410	579	397	379	357	157	367	374	278	205	***
October	420	79	197	187	111	332	3	89	260	10	***
November	0	1	113	0	20	0	6	80	0	0	***
December	0	0	0	0	0	13	0	2	0	0	***
Annual	**1982**	**2061**	**2111**	**1596**	**1806**	**1357**	**1948**	**1645**	**2064**	**1461**	***

4.2 Existing RWH Practice in Khulna City

Here are some pictures of the existing RWH system in Khulna city

Figure 2: Existing Rain Water Harvesting Practices in Khulna City Area

The above pictures reflects the present conditions of the RWH system in Khulna city. In most of the cases rainwater is collected by installing a pipe with the roof. At first the rainwater drops in the roof, then after going through the pipe it was collected in some pot,water bucket or in some cases, in a water tank. It is a matter of great concern that in most of the cases there is no system for separating the amount of collected rainwater from first flash water. There were a lot of problems associated with the rainwater collection process. One of the major problems is there was no system of cleaning the roofs as well as the pipelines. Poor maintenance of roof and gutters caused a lot of problems for them. So after using that for some days the collected water got contaminated with various dust and debris. Morover various dust, leaves,debris etc got stucked in the pipe day by day which caused a lot of problem in the natural flow of water through the pipe. Another problem was most of the people were not aware of the proper purification system of collected raiwater. Again there wasn't any filtration media for purification of the collected rainwater. It has also been seen that the storage tanks were not covered properly. Most of the tanks were covered with materials such as polythene,old fertilizer bag, old cement bag, galvinise sheet etc. So evaporation loss, contamination with dust, bird droppings, mosquito breeding and algal growth had been very common problems for them. These improvisation had caused water contamination leading to limited use of stored rainwater. It has also been seen that in some families there were few RWH units but wrong management of them promoted access of biological fauna into water tank. So at last it can be said that there is a lacuna in technological awareness among the rainwater users. This inadequacy has led to substandard construction by mansons, poor guttering, installing down pipes, wrong operation of first flush system etc. The situation could be modified by post construction operation and maintenance, training and subsequent periodic awareness programmes.

4.3 Survey Results and Users Opinion

In this section the results we got from the analysis of the questionnaire survey and field base survey is discussed. The educational qualifications of those surveyed people are shown in a graph below. Among those people 5% are totally illiterate, 8% people can only write their name, 30% have passed primary level education, 23% have passed in junior secondary level, 15% have got S.S.C certificate, 13% have got their H.S.C certificates and only 6% people have completed their graduation degree.

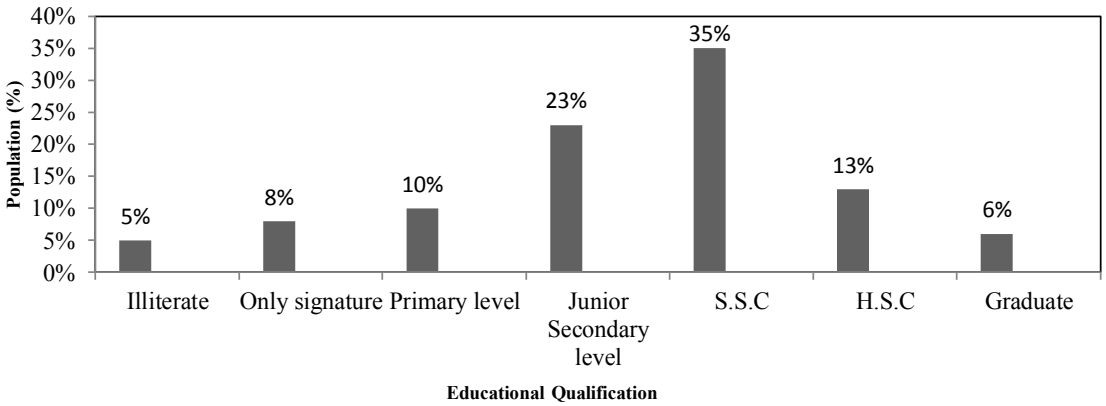

Figure 3: Educational qualification of the respondents

People in Khulna city have the practice to collect their rainwater in different pots, pans, drums and some people arrange a large tank may be made of RCC or Plastic. People use that collected rainwater in various purposes like drinking, cooking, washing clothes, bathing purpose, washing utensils, toilet purposes etc. The chart below shows the uses of rainwater.

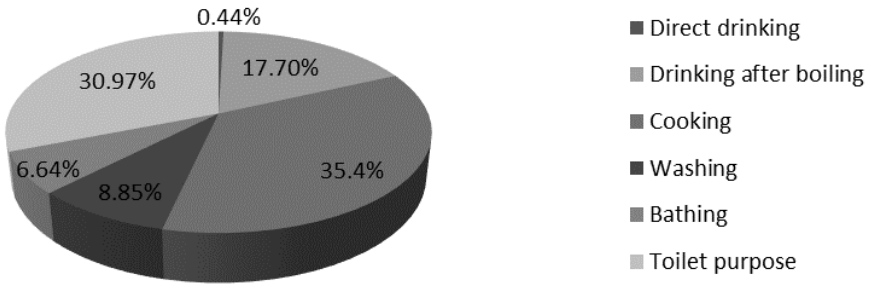

Figure 4: Proportions of Uses of Rainwater

Almost all people were conscious about the system of rainwater harvesting and its benefits. Approximately 80% people expressed that they had always liked the process and they think that this system will fulfill their necessities of water in future. They are also reliable on this system because of easy collecting system and low cost. 17% of people told that they didn't like this system because the amount of water was insufficient for them to use properly. About 3% people told that they neither like it nor dislike it.

Figure 5: Users Opinion

4.4 Proposed Filtration Model of rainwater harvesting system

A modified filtration system is built for getting purified rainwater from direct collected water. In existing rainwater harvesting system in Khulna city, there is no suitable option for separating total amount of rainwater from first flush. The first flush of rainwater contains a lot of pollutant within it including air and rooftop pollutants which can easily pollute the total amount of rainwater collected. In typical rainwater harvesting system rainwater is collected that lands on a roof and is then channeled down through guttering and pipe work to a storage tank. During dry periods of weather the roofs gets covered in a fine coating of dust together with leaves, bird droppings, and other debris. When it starts to rain these objects are washed straight off the roof and down the guttering or pipe. After a certain quantity of rain has been fallen, the loose dirt and debris virtually washed away and the water coming down the pipe can be assumed to be clean. So a technique named floating ball is used here for the separation of first flush of rainwater. It is a very simple technique. When the rain starts to fall, it accumulates together with any debris in a chamber with a conical top. As the chamber fills a ball floats on the collected water's surface. Eventually the ball becomes stuck in the conical chamber and therefore redirecting subsequent collected rainwater into the main clean water storage tank. A small bore pipe is used to empty it and dispatch the first flush water. The filtration system contains a filtration media and two pots for collection of water. After the fulfilling of the floating system one pot collects direct rooftop water and the other pot collects the filtrated water from the filtration media.

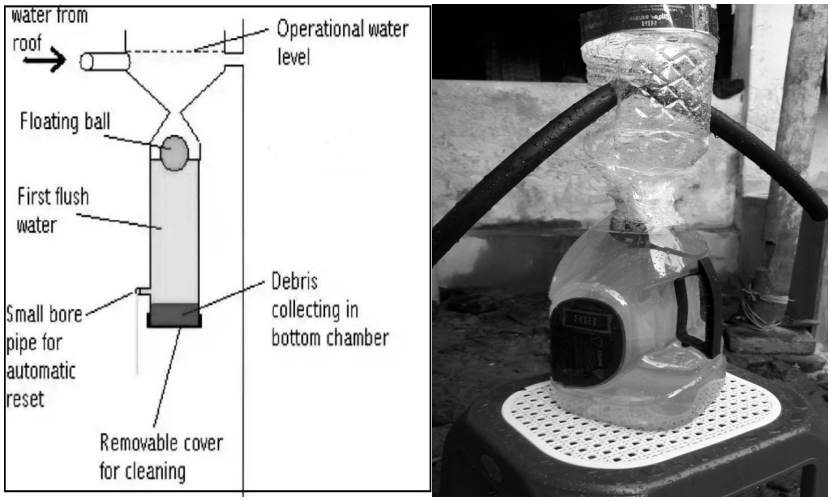

Figure 6: Floating Ball System

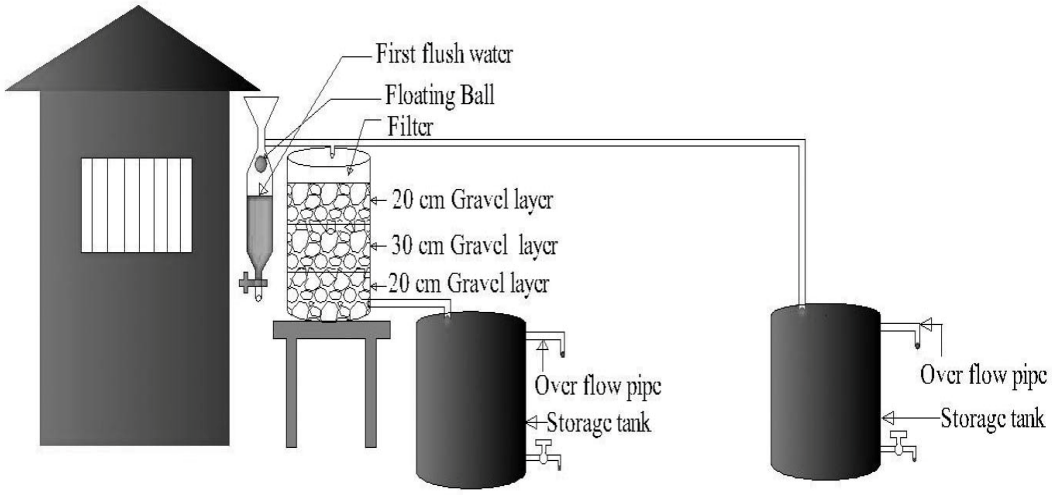

Figure 7: Proposed RWH model

4.5 Laboratory Based Analysis

Various laboratory tests were performed with those two water samples, one was directly collected and another was filtrated. The summary of test results of water quality parameters are presented below:

Table 2: Test results of stored rainwater quality

Name of test	Harvested Rain Water Quality		Bangladesh Standards for Drinking Purpose
	With Filtration	Without Filtration	
pH	7.13	7.15	6.5-8.5
Color (Pt-Co. Unit)	82	89	15
Turbidity (NTU)	8.07	10.07	10
Alkalinity (mg/L as $CaCO_3$)	25	25	130-150
Chlorine (Cl^-) Content (mg/L)	10	10	200-600
Total coliform (N/100mL)	0	15	0
E.coli (N/100mL)	0	1	0
BOD_5 (mg/L)	2.3	2.9	0.2
COD (mg/L)	112	144	4
Hardness (mg/L as $CaCO_3$)	32.4	50.9	200-500
Nitrate-N (mg/L)	0.2	0.4	10
Electrical Conductivity (µS/cm)	44.8	92.9	1200

From the laboratory based analysis it has been seen that in almost every cases the the water collected from the filtration media shows better result that the water which was collected directly. It has also been that expect some experimental values, almost all the result values of those tested sample were within the range of Bangladesh Standards for Drinking Purpose (ECR, 1997). It has been noticed that for both those samples the values of pH, Turbidity, Alkalinity, Chlorine, Total colifirm, E.coli, Hardness, Nitrate-N and Electrical conductivity satisfy the limitations of Bangladesh Standards for Drinking Purpose (ECR, 1997). But in the case of Color, BOD_5 and COD the experimental value exceeds the limits of standard values. The causes of exceedence of color limit can be due to higher amount of suspended and dissolved particles in water which is one of the limitations of my proposed filtration media. The samples from direct rainfall were more acidik due to contamination in the air.The contamination may be due to the emission of hazardous gases from transportation and industrial area. The rainwater collected from roof was affected by the contact of roof surfaces. So the main factors of the exceedence of BOD_5 is the changes in dissolved oxygen by organic wastes. Temperature, pressure, salinity etc are effected the dissolved oxygen content in the water. Exceedence of COD may be due to excess amount of organic pollutant in rainwater. So it can be said that with the further modification of the proposed RHW filtration model, those problems can be solved.

5. CONCLUSIONS

From the questionnaire survey it was seen that most of the people in Khulna city are aware of the collection of rainwater but many of them do not have any separate tank or other media to collect the water. Most people collect it directly to pot, bucket, vessel etc and almost 80 to 85% of people do not use any filtration media to filter the water. Few of them do not have faith in rainwater because their opinion is the collected rainwater cannot fulfill their monthly necessities and they don't know how to improve the RWH system as well as how to clean it. They further told that rainwater is available only 4 or 5 months in Bangladesh and that's why they have to find out other available options for water supply during the dry season. Laboratory base analysis result shows a great performance for the filtration media. The filtrated water shows a better value in all tests rather than direct

collected water. So it is clear that if this filtration media can be installed in Khulna city then all people can have safe rainwater and can use that water without any consciousness. As the cost of the filtration media is very low so almost every people in Khulna city have the capability to buy it or install it himself.

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