Physico-chemical parameters analysis of Rainwater collected in three time intervels

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ABSTRACT

The urban centers of developing countries like Khulna City in Bangladesh are facing air pollution and atmospheric wet deposition which can be used as a tool for monitoring the quality of air. This paper compares rain water quality of different months of monsoon period (July, August and September) in 2015. Only Khulna University is considered for the collection of rainwater, because it is situated near a residential area (Agrani Bank residential area) and a local bus terminal (Gollamari bus terminal). The geographical condition make it as a good option for monitoring rain water quality as well as finding the pollution level of the environment. Rainwater was collected from direct catch and roofs in Khulna University. Two types of roofs were used for the collection. They were concrete roof and Galvanized iron sheet roof. All water was collected in three different time variation (after 10, 20 and 40 minutes of raining). Physical parameters (pH, EC, TDS), Chemical Parameters (Sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Bicarbonate (HCO_3^-), Chloride (Cl^-), Sulphate (SO_4^{2-}), Nitrate - Nitrogen (NO_3^--N), Ortho-Phosphate (PO_4^{3-})) were tested. Whereas Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^- , PO_4^{3-}, *E. Coli*, faecal coliform, total coliform bacteria are present in lowest amount in direct catch than in concrete roof and Galvanized iron sheet roof.

By comparing with WHO and BSTI standards it is found that rainwater can be used for drinking purposes as well as for household works in dry season in KCC. But in Bangladesh it is not a well known approach. So initiatives should be taken for the better uses and management of rainwater.

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Introduction

In recent years a lot of efforts have been made to understand the physical and chemical processes which are responsible for the formation of acid species and their removal from atmosphere. Rainwater chemistry has been subjected to numerous investigations during the last two decades because of the increasing percentage of environmental problems caused by acid rain. Rainwater composition is important for understanding the role of transport of the atmospheric soluble components and the contribution of different sources of atmospheric pollutants.

The chemical composition of rainwater shows variations in characteristics from site to site and region to region, due to the influences of local sources. The processes which control the composition of rain are complex and influenced by both natural and anthropogenic sources. If the source is influenced by increasing man made activities then the rainwater will become acid because the anthropogenic activities contribute acidic gases like SO_2 and NO_x and basic gases like NH_3 (Kulshrestha *etal*, 2003). Acidity is mainly occur due to sulfur and nitrogen oxides emissions from fossil fuel combustion, which after being dispersed and being transported react chemically in the atmosphere before becoming wet or dry deposited as nitric and sulfuric acid or neutralized ammonium salts (Possanzini *etal*, 1988).

Considering the importance of acid rain and the relation that exists with the population growth in urban cities like Khulna, the aim of this paper is to gain an initial understanding of rainwater chemistry including its composition and possible sources in and urban locality in Khulna, where these kinds of data have not previously been available.

Literature Review

Chughta etal (2014) conducted a study of rainwater to observe the physico-chemical parameters of rainwater in Karachi, Pakistan during monsoon season (July to September, 2013). They collected rainwater as direct catch in clean polypropylene bowls from eighteen different towns of Karachi. Although, they suggested further studies are needed in order to complete this data with aspects such as organic deposition or dry deposition in order to create a complete database that permits evaluating modeling exercises and improving knowledge about future environmental and human health impacts.

Narayana etal (2014) conducted a study to observe the Quality of rainwater over Visakhapatnam City, India during summer, southwest monsoon and northeast monsoon periods of the years 1974-1977. He reported that the southwest monsoon rains show large variations in ionic concentrations when compared with summer and northeast monsoon rains. In general the ionic concentrations are observed to be decreasing from summer rains to northeast monsoon rains. Thunderstorm rains contribute very high sulphate concentrations whereas northeast monsoon rains exhibit very low values. It is observed that on an average various ionic concentrations are highly variable indicating the impact of complicated urban and marine environments of Visakhapatnam region. The difference between maximum and minimum values is particularly high during southwest monsoon period. The maximum concentrations of different ions in various seasons also show the highest values in southwest monsoon period.

E. Ramirez Lara etal (2009) conducted a study on chemical composition of rainwater in Northeastern Mexico. The sampling period of the study was January to December 2009. They have selected Monterrey as study area, which is the most important industrial area of North Mexico. The study reports the chemical composition of atmospheric wet deposition of this area. Thirty two samples of rain water were collected with automatic sampler and analyzed for pH, ion concentrations (Na^+, K^+, Ca^{2+}, Mg^{2+},NH^{4+}, Cl^-, SO_4^{2-}, NO_3^-) and conductivity. The results show that due to neutralization average weighted pH value of the rainwater was 6.58. The chemistry of rainwater showed high contributions of Ca^{2+} and Mg^{2+} in cations and Cl^- and SO_4^{2-} in anionic species. According to the study the local dust cement factories and surrounding limestone environment might cause high concentration of Ca^{2+} and Mg^{2+}. In conclusion they have said that the result can be used to evaluate the composition of atmospheric deposition, to evaluate air quality and to develop strategies to implement preventive measures and control of the atmospheric emissions in city of Northeast of Mexico. According to the researchers, this study represents as the first study of rainwater chemical composition in the Northeast of Mexico.

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Materials and Methods

Materials and methods includes data collection (primary data collection of water samples, analysis of water samples, field investigation, laboratory analysis; secondary data), procedure for determination of physical and chemical parameters under materials and methods.

Information and Data sources

The main sources of data and information are two types:

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Primary sources

The primary data sources mainly come from laboratory analysis of rain water quality parameter and field investigations.

Secondary sources

Secondary sources are*:*

- Bangladesh Water Development Board (BWDB)
- Bangladesh Bureau of Statistics (BBS)
- Institute of water and flood management, Bangladesh University of Engineering & Technology
- Khulna Municipality
- Web sites

Reconnaissance survey

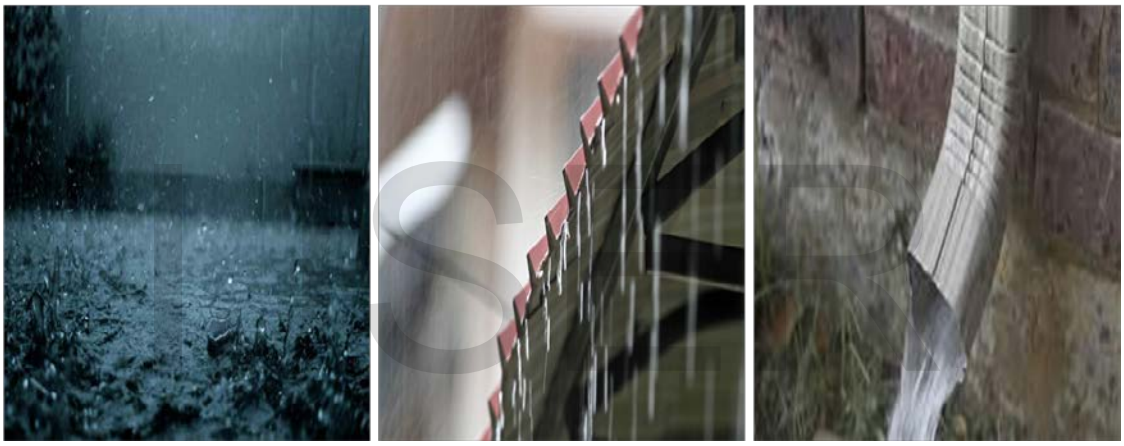
The research work includes a field's survey to locate the point of source of water. At the starting of the research, Khulna city corporation map was collected. Then 14 spots were selected as sampling locations in map (Figure 1).

Selection of the sampling spots

The purposive (Non-probability) sampling technique was followed where the particular units were selected for constituting a sample on the basis that the small mass that they so selected out of huge one were typical or representative of the whole. The sampling time is monsoon period (July to September).

Sampling Design

The sampling was conducted for three months (July, August and September) from each location with a one month interval. The collection of rainwater was done by three ways. They are direct catch, water runoff from concrete roof and water runoff from galvanized iron sheet roof. From Khulna University nine samples were collected every month. First three samples from direct catch, concrete roof and galvanized iron sheet roof (shown in figure 1 (a), (b) and (c) respectively) at the starting of rainfall. Then another three samples were collected same as before after 10 minutes of raining. The last three samples were collected after 40 minutes of raining. Total Number of samples collected in every month was 48. Total amount of three months rain water sample was (48X3 = 144).



(a) Direct catch (b) Galvanized iron sheet roof (c) Runoff from concrete roof

Figure 1: Rain water collection

Sampling Procedure

Every possible precaution was taken to obtain a representative sample which is the most important part for the accuracy of analytical results. For sampling, firstly 27 plastic bottles were collected and washed well with household water 6 or 7 times and then, by entering 1-2 ml 95-98% industrial sulfuric acid with water (to remove foreign chemicals) in to every bottles. The bottles were then sealed well and preserved for one night. After that, every bottle was properly washed by shaking with water again 6 or 7 times and then preserved in room temperature. The capacity of every sample bottle was 1 liter. Before sampling, the bottle was rinsed with distilled water and sample water 3 or 4 times so that the sample could represent the total characteristics of the rain water. Then the water sample was collected in sampling bottles and then securely sealed with proper leveling (sample number and location). Aeration during sampling was avoided as far as possible.

Laboratory investigation

Before analysis all the instruments were checked properly to insure technical sophistication. The water samples were transfer carefully to the laboratory and put in a refrigerator for laboratory analysis. Precision and accuracy were also considered properly to get the better results.

Water sample analysis

Before chemical analysis all samples were visually estimated either odor/color more or turbidity or any other extraneous material. For chemical analysis of the water samples a number of sophisticated instruments and established world recognized analytical methods were followed. To measure the drinking water quality of the collected sample, following tests were performed.

Parameters analyzed for the study

In this exploratory type of study, the chemistry of major cations and anions were primarily examined. For this sake, the following water quality parameters including major cations and anions have been analyzed in the laboratory presented in the Table 1.

Table 1: Analyzed Parameters

<table>
<tr><th rowspan="2">Physical Parameter</th><th colspan="2">Chemical Parameter</th><th rowspan="2">Microbiological parameter</th></tr>
<tr><th>(Major cations)</th><th>(Major anions)</th></tr>
<tr><td rowspan="2">pH</td><td>Sodium (Na^+)</td><td>Bicarbonate (HCO_3^-)</td><td rowspan="2">E.Coli</td></tr>
<tr><td rowspan="2">Potassium (K^+)</td><td rowspan="2">Chloride (Cl^-)</td></tr>
<tr><td rowspan="2">Electrical Conductivity (EC)</td><td rowspan="2">Faecal Coliform</td></tr>
<tr><td>Calcium (Ca^{2+})</td><td>Sulphate (SO_4^{2-})</td></tr>
<tr><td rowspan="2">Total Dissolved Solid (TDS)</td><td rowspan="2">Magnesium (Mg^{2+})</td><td>Nitrate -Nitrogen (NO_3^--N)</td><td rowspan="2">Total Coliform</td></tr>
<tr><td>Ortho-Phosphate (PO_4^{3-})</td></tr>
</table>

Analytical Methods

Different analytical methods were adopted for the determination of major cations and anions of the rain water. The analytical methods used to conduct the present study are enlisted in Table 2.

Table 2: Analytical methods used to determine the rain water chemistry

Parameters	Unit	Methods/Instrument	References
p^H (Hydrogen Ion Concentration)		HANNA instruments, p^H 211 (Microprocessor p^H meter)	**Ramesh and Anbu, 1996.**
EC (Electrical Conductivity)	s/cm	TDS meter (H1-9635, portable water proof Multirange Conductivity/TDS meter)	
TDS (Total Dissolve Solids)	Ppm	TDS meter (H1-9635, portable water proof Multirange Conductivity/TDS meter)	
Sodium (Na^+)	Ppm	Flame photometric method (Flame photometer- models PEP 7 and PEP 7/C	.
Potassium (K^+)	Ppm	Flame photometric method (Flame photometer- models PEP 7 and PEP 7/C)	
Calcium (Ca^{++})	Ppm	Titrimetric method	
Magnesium (Mg^{++})	Ppm	Titrimetric method	
Bicarbonate (HCO_3^-)	Ppm	Potential methods	
Dissolve silica (H_4SiO_4)	Ppm	Molybdo-silicate method (Thermo spectronic, UV-visible Spectrophotometers)	
Ortho-Phosphate (PO_4^{3-})	Ppm	Ascorbic acid method (Thermo spectronic, UV-visible Spectrophotometers)	**Ramesh and Anbu, 1996.**
Sulfate (SO_4^{2-})	Ppm	Turbidimetric method (Thermo spectronic, UV-visible Spectrophotometers)	
Chloride(Cl^-)	Ppm	Ion selective electrode methods, (Cole-Parmer iodine electrode, model no. 27502-13)	**Electrode manual.**

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Microbiological Method

Streak Plate Technique is used.

Data Processing and Analysis

The collected data were checked, verified and edited to remove errors, omissions and inconsistencies. The edited data were coded before processing and tabulation. Methods were followed to increase the degree of accuracy of data.

The data were processed and analyzed by using MS Excel of Office 2007 version. All the results of interpretation are presented in Tables and graphs. Decreasing amount of parameters in harvesting pots is discussed.

Result and Discussion

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Rainwater gets the compositions largely by dissolving particulate materials in the atmosphere (upper troposphere) when droplets of water nucleate on atmospheric particulates, and secondarily by dissolving gasses from the atmosphere. Rainwater compositions vary geographically (Issaka, 2011). The major components of rain water are Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, SO_4^{2-}, PO_4^{3-}, and NO_3^-. In the present chapter an effort has been made to evaluate the quality of the harvested rainwater collected from different pots for drinking purposes with respect to the above mentioned parameters and standards (Bangladesh Standards and Testing Institution (BSTI) and World Health Organization (WHO)). For determining the portability of rain water microbiological characteristics of the rain water is also discussed in this chapter.

Physico-chemical Characteristics of the Harvested Rainwater

Compositions of the rain water have showed a distinct feature during the study period. The chemistry of the harvested rainwater was governed by the major anions and cations.

The average value of rain water quality parameters (collected from direct catch, concrete roof and galvanized iron sheet roof) of different time periods of Khulna University shows very little change in the physico-chemical parameters (Table 3, 4 and 5) during monsoon period.

Table 3: Physico-chemical parameters of rain water collected from direct catch from Khulna University in different time periods at monsoon

Time	Direct Catch

	pH	EC (µs/cm)	TDS (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Cl^{-} (mg/l)	HCO_3^{-} (mg/l)	SO_4^{2-} (mg/l)	NO^{3-} (mg/l)	PO_4^{3-} (mg/l)
After 10 minutes of raining	5.77	44.55	22.28	2.81	1.41	0.76	0.03	3.28	5.59	2.58	1.50	0.55
After 20 minutes of raining	5.61	40.79	20.39	2.69	1.35	0.69	0.03	3.17	5.24	2.45	1.36	0.50
After 40 minutes of raining	5.41	39.58	19.79	2.53	1.26	0.68	0.03	2.72	4.93	2.17	1.25	0.50

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Table 4: Physico-chemical parameters of rain water collected from concrete roof from Khulna University in different time periods at monsoon

Time	Concrete Roof											
	pH	EC (µs/cm)	TDS (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Cl^{-} (mg/l)	HCO_3^{-} (mg/l)	SO_4^{2-} (mg/l)	NO^{3-} (mg/l)	PO_4^{3-} (mg/l)
After 10 minutes of raining	6.60	43.71	21.85	3.60	1.80	1.81	0.04	4.17	5.56	3.35	2.34	0.71
After 20 minutes of raining	6.36	40.59	20.29	3.51	1.76	1.10	0.04	3.73	5.85	3.23	1.92	0.67
After 40 minutes of	6.03	37.79	18.90	3.36	1.68	1.02	0.04	3.49	5.27	2.92	1.84	0.61

raining												

Table 5: Physico-chemical parameters of rain water collected from galvanized iron sheet roof from Khulna University in different time periods at monsoon

Time	Galvanized iron sheet roof roof											
	pH	EC (µs/cm)	TDS (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Cl^{-} (mg/l)	HCO_3^{-} (mg/l)	SO_4^{2-} (mg/l)	NO^{3-} (mg/l)	PO_4^{3-} (mg/l)
After 10 minutes of raining	6.98	48.61	24.31	3.48	1.74	1.01	0.05	4.07	6.43	3.20	1.63	0.65
After 20 minutes of raining	6.58	45.69	22.84	3.26	1.63	0.95	0.05	3.83	6.11	3.05	1.59	0.51
After 40 minutes of raining	6.32	43.37	21.69	3.14	1.57	0.90	0.05	3.65	5.86	2.87	1.49	0.49

From Table 3, 4 and 5 it can be concluded that the amount of EC, TDS along with others parameters decrease with the increasing time of raining. Lowest amount of EC, TDS, cations and anions are present in the rain water which is collected after 40 minutes of raining in direct catch.

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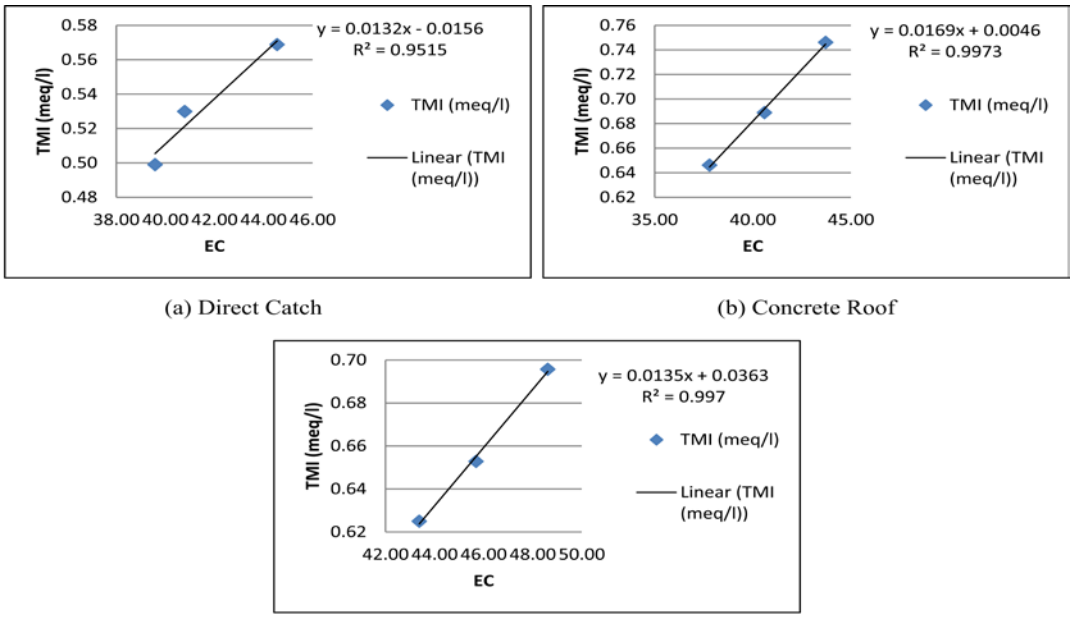

(a) Direct Catch

(b) Concrete Roof

(c) Galvanized Iron Sheet

Figure 2: Relation between EC and TMI (meq/l) of onsite rain water in Khulna University

The average value of pH of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 3).

Electro neutrality of analyzed data of onsite and harvested rain water

The accuracy of the analysis for major ions has been estimated from the Electro neutrality (E.N.) condition since the sum of positive and negative charges in the water must balance. The accuracy of rain water analyses is checked because the solution must be electrically neutral (Hounslow, 1995). Therefore, the sum of cations in rain water sample in meq/l should equal the sum of the anions in rain water sample in meq/l. For this purpose, cations and anions of the rain water samples are expressed in meq/l. Total cations and total anions are also calculated to show cation-anion balance. The sums are taken over the cations Na^+, K^+, Ca^{2+} and Mg^{2+}, and anions Cl^-, NO_3^-, HCO_3^-, SO_4^{2-} and PO_4^{3-}. The Electro neutrality (E.N) condition of the rain water samples were calculated from the following equation (1).

$$\text{Electro Neutrality (E.N, \%)} = \frac{\text{Sum of Cations} - \text{Sum of Anions}}{\text{Sum of Cations} + \text{Sum of Anions}} \times 100 \text{--------(1)}$$

$$\text{Or (E.N, \%)} = \frac{T_Z^+ - T_Z^-}{T_Z^+ + T_Z^-} \times 100 \text{ ---------- (2)}$$

Where, Tz+ represents sum of cations and Tz- represents sum of anions.

Total cations and anions of the rain water samples along with their respective E.N. values are listed in Appendix-A (Table A1 to A7) show that the E.N. value of all samples are within 10%

except rain water collected from concrete roof at Khulna university in the month of September are +10.86. So, if the balance calculated is less than 10% then the analysis is assumed to be good. And it may be assumed that analyses were good and reliable.

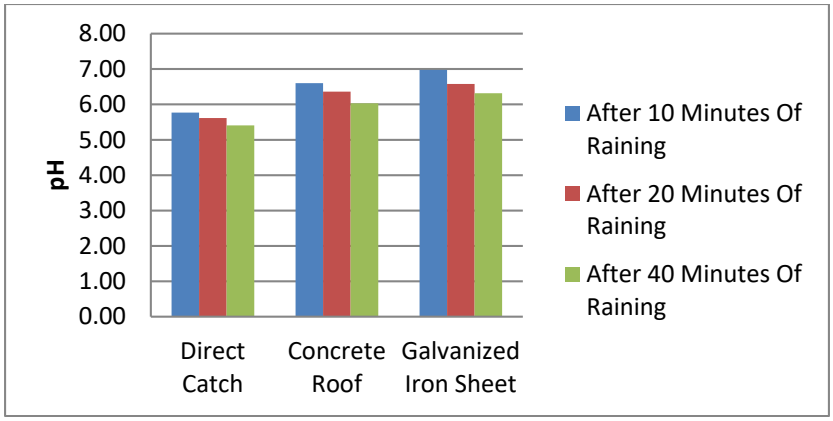

Figure 3: pH of onsite rain water collected from Khulna University in different time periods

From figure 3 it is seen that the chemical composition of rain water is variable with pH ranging from 5.41 to 6.98 with an average of 6.18 in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University. From the average value it can be said that it is acidic water.

According to WHO standard pH value range is 6.5-8.5 and according to BSTI standard pH value range is 6.4-7.4 for drinking water. All the samples contain pH within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of EC of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 4).

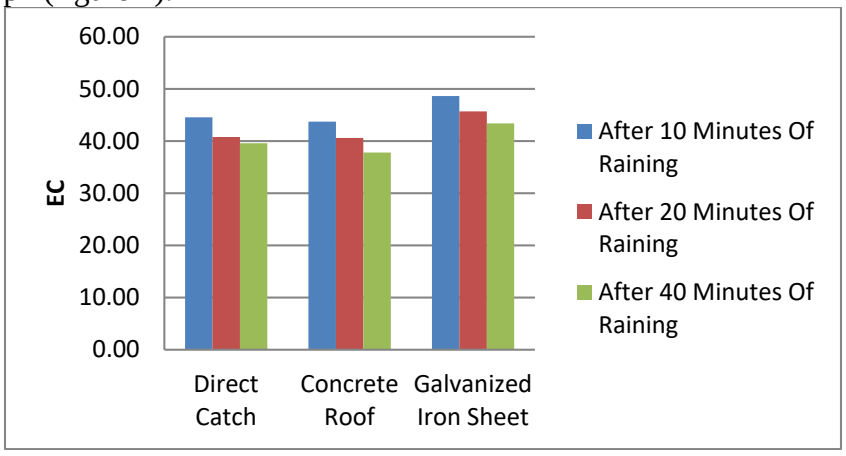

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Figure 4: EC of onsite rain water collected from Khulna University in different time periods

From figure 4 it is seen that the chemical composition of rain water is variable with EC ranging from 37.79 (µs/cm) to 48.61 (µs/cm) with an average of 42.74 (µs/cm) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO standard EC value range is 300 (µs/cm) for drinking water. All the samples contain EC within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of TDS of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 5).

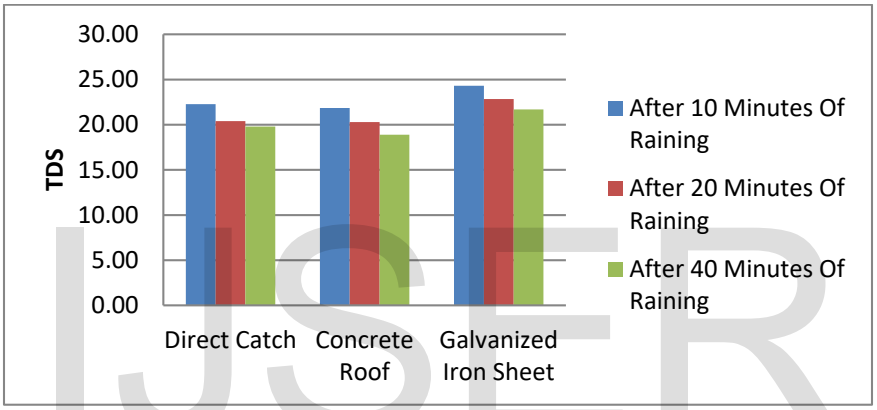

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Figure 5: TDS of onsite rain water collected from Khulna University in different time periods

From figure 5 it is seen that the chemical composition of rain water is variable with TDS ranging from 18.90 (mg/l) to 24.31 (mg/l) with an average of 21.37 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO standard TDS value range is 1000 mg/l and according to BSTI standard TDS value range is 500 mg/l for drinking water. All the samples contain TDS within this range. So it can be said that the rain water is safe for drinking purpose.

Variation in ion chemistry of rain water

Average value of Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, HCO^{3-}, SO_4^{2-}, PO_4^{3-}, and $NO3^{-}$ of rain water collected in monsoon period which are presented in mg/l in Appendix (Table B1, B2 and A7) and in graphs under this section.

Major Cations of rain water

The average value of Ca^{2+} of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 6).

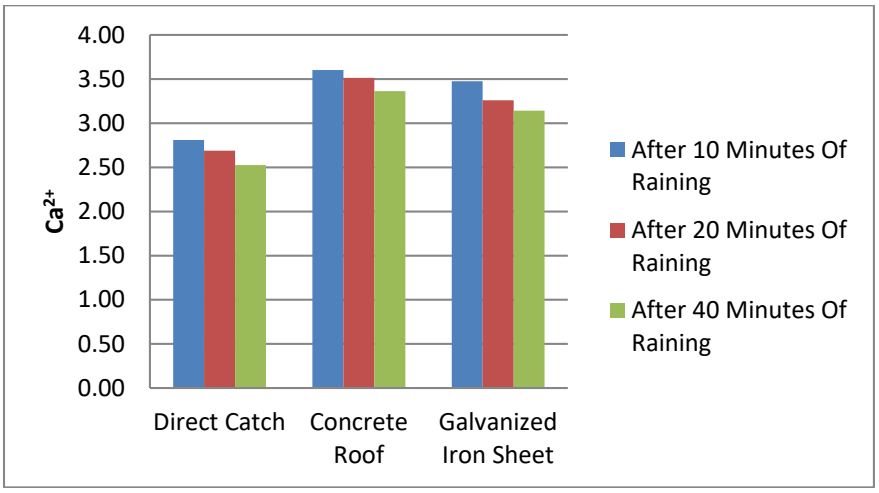

Figure 6: Ca^{2+} of onsite rain water collected from Khulna University in different time periods

From figure 6 it is seen that the chemical composition of rain water is variable with Ca^{2+} ranging from 2.53 (mg/l) to 3.60 (mg/l) with an average of 3.15 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard Ca^{2+} value range is within 75 (mg/l) for drinking water. All the samples contain Ca^{2+} within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of Mg^{2+} of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 7).

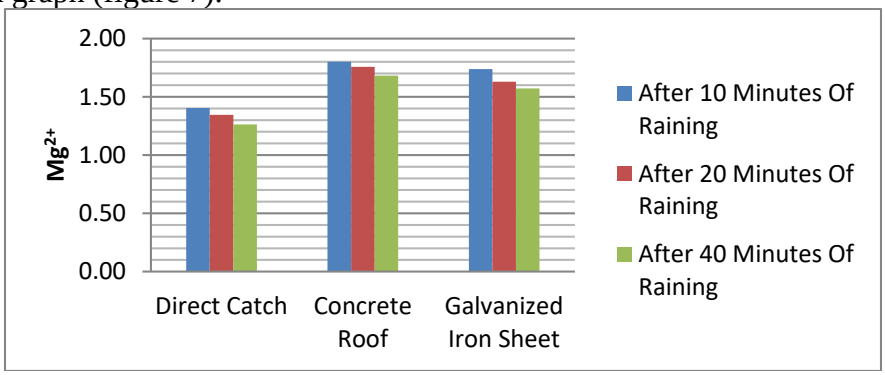

Figure 7: Mg^{2+} of onsite rain water collected from Khulna University in different time periods

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From figure 7 it is seen that the chemical composition of rain water is variable with Mg^{2+} ranging from 1.26 (mg/l) to 1.80 (mg/l) with an average of 1.58 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard Mg^{2+} value range is within 65 (mg/l) for drinking water. All the samples contain Mg^{2+} within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of Na^+ of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 8).

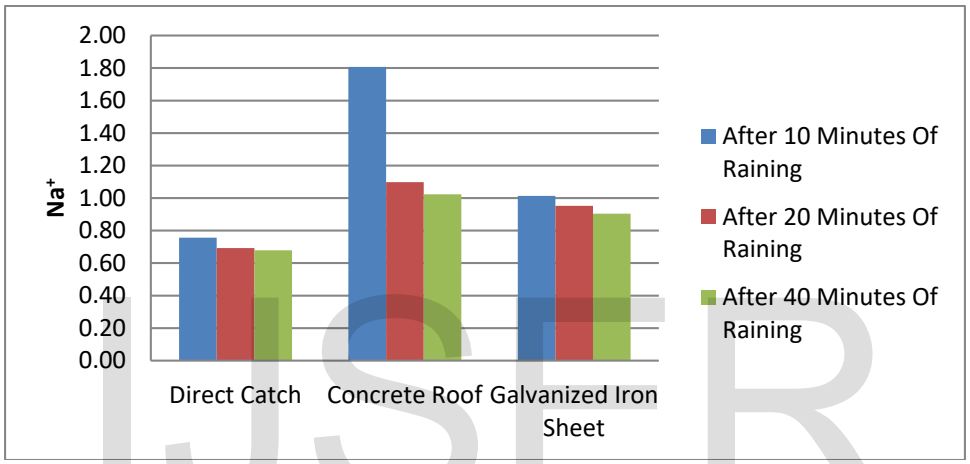

Figure 8: Na^+ of onsite rain water collected from Khulna University in different time periods

From figure 8 it is seen that the chemical composition of rain water is variable with Na^+ ranging from 0.68 (mg/l) to 1.81 (mg/l) with an average of 0.99 (mg/l)in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard Na^+ value range is within 200 (mg/l) for drinking water. All the samples contain Na^+ within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of K^+ of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 9).

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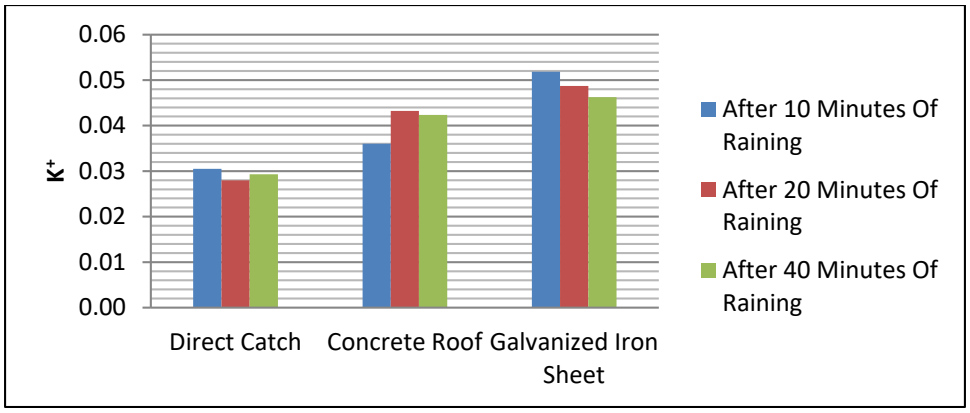

Figure 9: K^+ of onsite rain water collected from Khulna University in different time periods

From figure 3.25 it is seen that the chemical composition of rain water is variable with K+ ranging from 0.03 (mg/l) to 0.05 (mg/l) with an average of 0.04 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard K^+ value range is within 20 (mg/l) for drinking water. All the samples contain K^+ within this range. So it can be said that the rain water is safe for drinking purpose.

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Major anions of rain water

The average value of Cl^- of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 10).

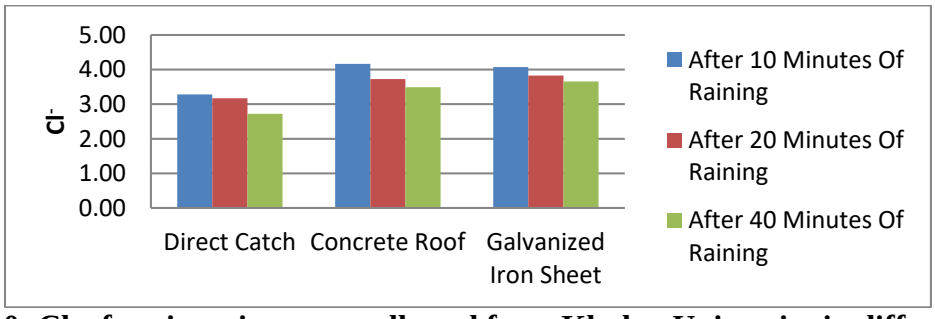

Figure 10: Cl^- of onsite rain water collected from Khulna University in different time periods

From figure 10 it is seen that the chemical composition of rain water is variable with Cl^- ranging from 2.72 (mg/l) to 4.17 (mg/l) with an average of 3.57 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard Cl^- value range is within 250 (mg/l) for drinking water. All the samples contain Cl^- within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of HCO_3^- of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 11).

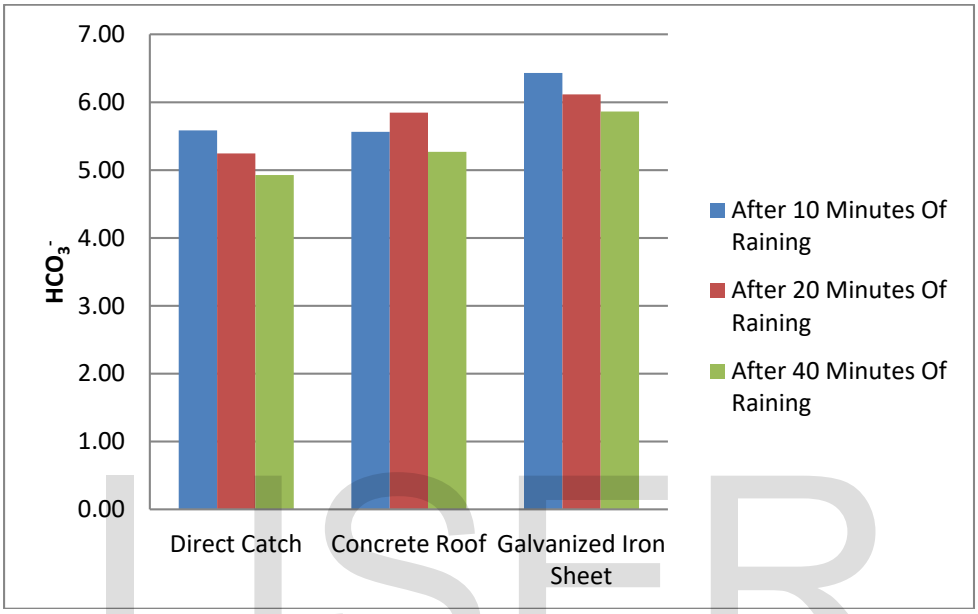

Figure 11: HCO_3^- of onsite rain water collected from Khulna University in different time periods

From figure 11 it is seen that the chemical composition of rain water is variable with HCO_3^- ranging from 4.93 (mg/l) to 6.43 (mg/l) with an average of 5.65 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard HCO^{3-} value range is within 500 (mg/l) for drinking water. All the samples contain HCO^{3-} within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of SO_4^{2-} of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 12).

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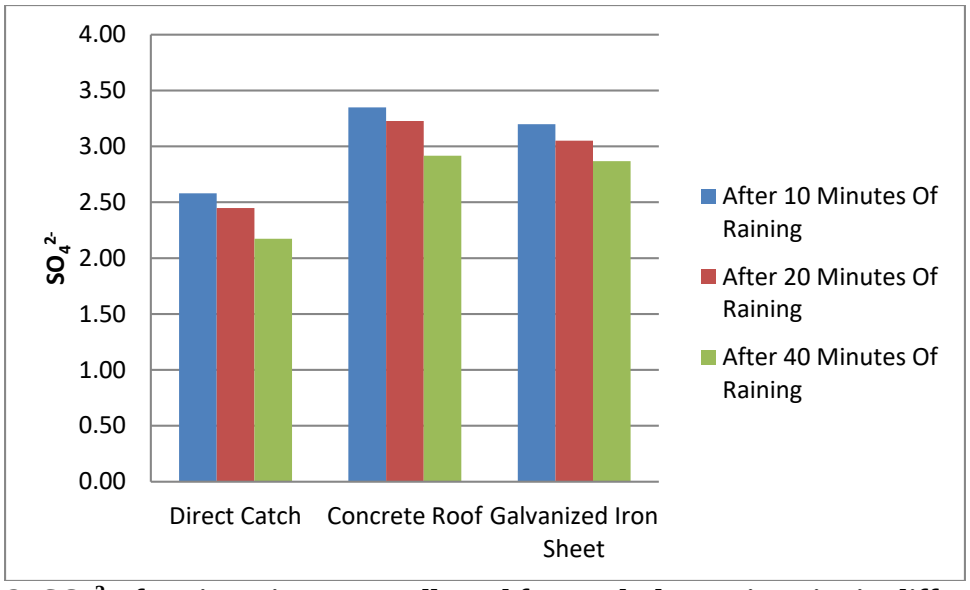

Figure 12: SO_4^{2-} of onsite rain water collected from Khulna University in different time periods

From figure 12 it is seen that the chemical composition of rain water is variable with SO_4^{2-} ranging from 2.17 (mg/l) to 3.35 (mg/l) with an average of 3.87 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard SO_4^{2-} value range is within 250 (mg/l) for drinking water. All the samples contain SO_4^{2-} within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of NO_3^- of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 13).

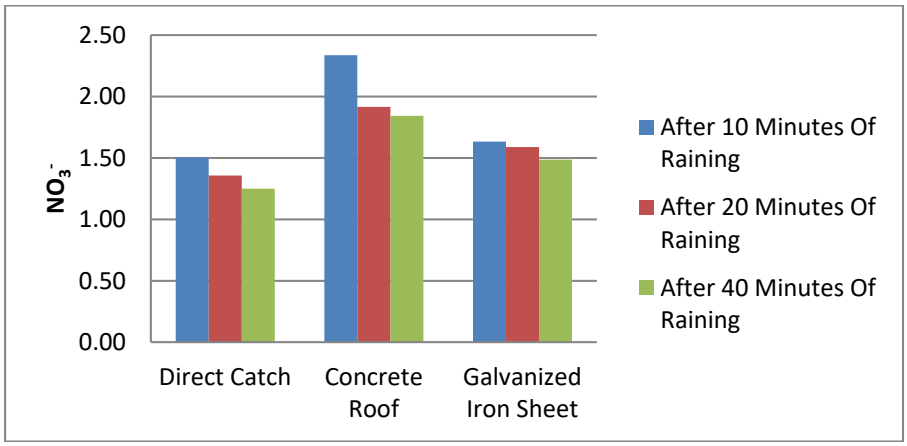

Figure 13: NO_3^- of onsite rain water collected from Khulna University in different time periods

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From figure 14 it is seen that the chemical composition of rain water is variable with NO_3^- ranging from 1.25 (mg/l) to 3.34 (mg/l) with an average of 1.66 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard NO_3^- value range is within 4.5 (mg/l) for drinking water. All the samples contain NO_3^- within this range. So it can be said that the rain water is safe for drinking purpose.

The average value of PO_4^{3-} of rain water (collected from direct catch, concrete roof and galvanized iron sheet roof) during monsoon period at different time periods of Khulna University is presented in graph (figure 14).

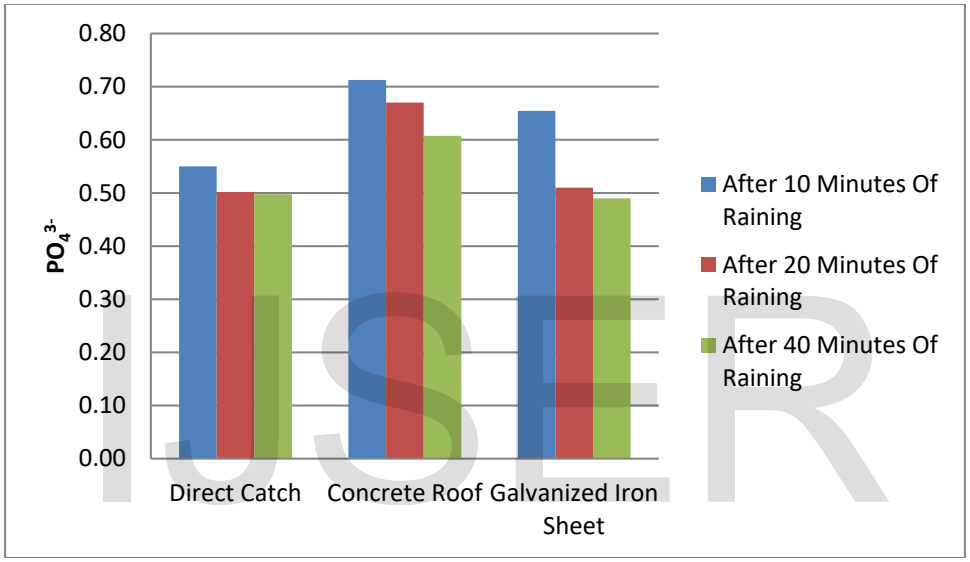

Figure 14: PO_4^{3-} of onsite rain water collected from Khulna University in different time periods

From figure 14 it is seen that the chemical composition of rain water is variable with PO_4^{3-} ranging from 0.50 (mg/l) to 0.71 (mg/l) with an average of 0.58 (mg/l) in collected water from direct catch, concrete roof and galvanized iron sheet roof in three different time periods in Khulna University.

According to WHO and BSTI standard PO_4^{3-} value range is within 3 (mg/l) for drinking water. All the samples contain PO_4^{3-} within this range. So it can be said that the rain water is safe for drinking purpose.

CONCLUSION

The problem of water scarcity, together with increasing environmental awareness, the development of more stringent regulations on water quality and use and the need for sustainable approaches in water management related activities have increased the potential for alternative water resources. In this framework, the analysis of alternative water resources, such as rainwater, is becoming increasingly popular as a sustainable source of water with a reduced impact on the environment. So use of rainwater is a very good option for the sustainable management of drinking water. In Bangladesh it is not very popular way but some people use it for household works.

From the study it has been found that rainwater collected from Khulna University in different time periods show that rain water became cleaner with the increasing time of raining. So rain water as potential source of drinking water can be used in Khulna City Corporation area.

Further study is suggested for the better and easy management of storage rain water along with instrumental set up in broad. Trace elements test of rain water will improve future study.

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