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Hydrological Analysis for Annual Rainwater Harvesting Potential in BCREC Campus

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Abstract — The technical aspect of this paper is to analyse the harvested rainwater from the hydrological point of view. First of all, the considerable catchment area is found out. Total rainwater which is collected from rooftops of different buildings like departmental buildings and hostel buildings at BCREC Durgapur Campus. Then, hydrological and topographic data of the considered catchment area has been collected. Finally, the water harvesting capacity from different buildings is evaluated. Alongside, a parametric study is done to show the variation of discharge throughout the year. Finally, the potential of harvested water in number of days is estimated to find out the effectiveness of the rainwater harvesting system in BCREC campus.

Keywords — ***Rainwater Harvesting, Harvesting Potential, Runoff Coefficient, Catchment Area, Rapid Depletion Method.***

1. INTRODUCTION

Water scarcity is one of the widely accepted problems in several parts of our country. To overcome this adverse situation various solutions and their applicability are nurtured by professionals. Rainwater Harvesting is one of the most popular processes for this purpose. Recent researches astonishingly have concluded that high population growth and rising economic condition in our country, increase the surface water demand exponentially. Besides, surface water and ground are concerned with the rising cost as well as ecological problems. In these altered circumstances, researchers are giving focus on rainwater harvesting as a perfect replacement over ground water as well as surface water. Rainwater harvesting being an economical and relatively simple and scientific process to manage our limited water resources, it is seemed to be a sustainable solution for community water supply. Water scarcity is such an alarming issue that it should be dealt carefully, so that development of the country will not hamper. For a solution to this the water scarcity problem, rain water harvesting is initiated in different countries. In this regard, Germany has played the leading role. They build the Biggest harvesting system at Frankfurt Airport, with a huge water collection capacity. [1,2,3]. Singapore having a very high annual rainfall, approximately 2400 mm, this country has put a significant impression in rainwater harvesting application [4,5,6]. In Tokyo RWH system is incorporated to reserve water which meets the emergency water demands during seismic disaster [7,8,9].

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In order to meet our daily demand of water requirement and reserve for the future purpose, alternative relatively economical and effective technological methods need to be introduced [10,11,12]. Hence, harvesting of rain water is seemed to be one of the best scientific methods to serve the purpose. Studies were conducted in the region of Khuskera-Bhiwari Neemrana Investment Region (KBNIR) to estimate the amount of harvesting of rain water from rooftop [13,14,15]. In this study house sizes and population are considered as the affecting factor for the rainwater harvesting process. From this study, it is estimated that if 50 % of the resident houses and all the service buildings of that region is involved for the harvesting purpose then 100% of the drinking water requirement of that region could be served. Saini et al. [16,17] tried to conserve rain water from the roof top using cheapest material and simplest design which may be incorporated as low-cost harvesting system in rural areas. Patel et al. [18,19] introduced the simpler and effective methods to solve the water scarcity problem by rain water harvesting from the different parts of buildings and surrounding areas. The technical aspect of this paper is to analyse the harvested rainwater from the hydrological point of view. Total rainwater is collected from rooftops of different buildings at BCREC Durgapur Campus. First of all, required data i.e., catchment areas & hydrological rainfall data has been collected. Then the water harvesting potential for different buildings is evaluated. Alongside, a parametric study is done to show the variation of discharge throughout the year. Finally, the relationship between water-harvest to water consumption is establish to analyse the utility of the harvested water.

2.PROPOSED TECHNIQUE TO ANALYSE RAIN WATER HARVESTING POTENTIAL

Based on the feasibility and campus status, BCREC, Durgapur administrative body given a thorough attention on the scarcity of water. Durgapur, India being the dry and low rainfall area harvesting and reserving rainwater is seemed to be proven as a best scientific solution to fight against water scarcity inside campus. Owing to its easy, scientific and low-cost installation and construction technique rainwater harvesting is already implemented inside BCREC Durgapur campus. But the potentiality of the rain water harvesting system that is already installed in the campus is not analysed yet. So, here in this study a simple mathematical analysis is carried to evaluate the potential day of the estimated potential rainwater. The harvested rainwater is assumed to be used in the residential parts of the campus with no limitation. Potential number of days for individual month is also estimated. Finally, the amount of water that is required excess of that harvested water is estimated. Following steps are followed during the study.

A. Collection of rainfall data

Geographical position of the city Durgapur is at 23.55°N 87.32°E. It has an elevation of 65 metres (213 ft) in district of Bardhhaman, West Bengal. Durgapur experiences a somewhat transitional climate between the tropical wet and dry climate of Kolkata and the more humid subtropical climate further north. Summers are extremely hot and dry, lasting from March to the middle of June, with average daily temperatures near 40°C. They are followed by the monsoon season with heavy precipitation and somewhat lower temperatures. Durgapur receives most of its annual rainfall during this season. The monsoon is followed by a mild, dry winter from November to January. The average monthly rainfall data of Durgapur shown in Table 1, is taken from the worldweatheronline.com website. As Durgapur is a small city, it has uniform average rainfall though out the city in all location. Thus, monthly rainfall data of the Durgapur city is assumed to be same for the station of BCREC Durgapur campus.

Table 1 - Monthly rainfall data of Durgapur station.

Sl. No.	Month	Rainfall(mm)
1	January	24.7
2	February	11.4
3	March	45.9
4	April	112.1
5	May	182.6
6	June	238.5
7	July	336.5
8	August	369.8
9	September	511
10	October	401.5
11	November	8.7
12	December	7.2
	Total	2249.9

B. Determination of Catchment Area

Total area from which the rain water drains into the considered water body is called catchment area. Here, the rain water harvesting reservoir is considered as the water body. All the rooftops of all the buildings inside the college campus is taken as the catchment area for this purpose. Total catchment area is calculated and shown in table 2.

Table 2 - Calculation of rooftop area of all building.

Serial no.	Building Name	Rooftop area (m^2)
1	AJC BOSE BHAWAN	241.47
2	SBI BANK BUILDING	196.98
3	MANAGEMENT HOUSE	164.64
4	BBA BUILDING	742.08
5	CANTEEN	69.18
6	OLD MCA BUILDING	264.84
7	MEDICAL UNIT	78.96
8	MECHANICAL BUILDING	374.77
9	VIDYASAGAR BHAWAN	519.04
10	APC ROY (C.E.) BUILDING	466.2
11	AURBINDO BOY'S HOSTEL	529.92
12	SATYAN BOSE BOY'S HOSTEL	939.09
13	CHITTRANJAN BOY'S HOSTEL	452.1
14	MAIN BUILDING	2087.05
15	CENTRAL LIBRARY	344.44
16	NIVEDITA GIRL'S HOSTEL	552.62
17	MOTHER TERESA GIRLS' HOSTEL	441.89
18	PROFESSOR ENCLAVE	530.69
19	MULTI GYM	193.06
20	STUDIO APPARTMENT I	166.4
21	STUDIO APPARTMENT II	172.8
	Total	9528.22

C. Hydrological analysis

The total amount of water that is received from rainfall over an area is called the rainwater legacy of that area. And the amount that can be effectively harvested is called the water harvesting capacity. The formula for calculation for harvesting capacity or volume of water received or runoff produced or harvesting capacity is given as

Harvesting capacity or Volume of water Received (m3) = Area of Catchment (m2) X Amount of rainfall (mm) X Runoff coefficient

Runoff coefficient for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface. Runoff coefficient accounts for losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation, which will all contribute to reducing the amount of runoff. Runoff coefficient varies from 0.5 to 1.0. In present problem statement, runoff coefficient is equal to 1 as the rooftop area is totally impervious. Eco-Climatic condition (i.e. Rainfall quantity & Rainfall pattern) and the catchment characteristics are considered to be most important factors affecting rainwater capacity. Table 3 and table 4 showing the value of runoff coefficient with respect to types of surface areas. Here in this study, a value of 0.7 for conventional roof is considered as runoff coefficient (K).

Table 3 - The value of runoff coefficient with respect to types of surface areas.

TYPE OF AREA	RUNOFF COEFFICIENT (K)
Residential	0.3-0.5
Forests	0.5-0.2
Commercial & industrial	0.9
Parks & Farms	0.05-0.3

Table 4 - Runoff Coefficients of Different Surfaces.

DIFFERENT SURFACES	RUNOFF COEFFICIENT (K)
Roof Conventional	0.7-0.8
Roof Inclined	0.85-0.95
Concrete /Kota paving	0.6-0.7
Gravel	0.5-0.7

D. Annual rainwater harvesting capacity

Using the formula discussed above, the total amount of water that may be harvested is estimated from different buildings. The result is shown in table 5. In the calculation a run-off coefficient value of 0.7 is taken. Total annual rainfall in a year is calculated from table 1 and that value is considered as annual rainfall (I) in meter. From the table it is shown that a discharge of 0.000798 m3/s or 7.98 litre/second, almost 8 litre/second can be obtained from the annual precipitation. The variation of discharge over different buildings through-out the year is shown in fig. 1.

Table 5 - Calculation of rooftop area of all building.

Building No.	Building Name	Run-off coefficient	Annual Rainfall (I) in m.	Catchment Area (A) in m^2	Water harvested (m^3)	Discharge Q (m^3/s)
B1	AJC BOSE BHAWAN	0.7	2.2499	241.47	380.29	0.000202365
B2	SBI BANK BUILDING	0.7	2.2499	196.98	310.22	0.00016508
B3	MANAGEMENT HOUSE	0.7	2.2499	164.64	259.29	0.000137977
B4	BBA BUILDING	0.7	2.2499	742.08	1168.72	0.000621904
B5	CANTEEN	0.7	2.2499	69.18	108.95	5.79767E-05
B6	OLD MCA BUILDING	0.7	2.2499	264.84	417.10	0.000221951
B7	MEDICAL UNIT	0.7	2.2499	78.96	124.35	6.61729E-05
B8	MECHANICAL BUILDING	0.7	2.2499	374.77	590.23	0.000314078
B9	VIDYASAGAR BHAWAN	0.7	2.2499	519.04	817.45	0.000434984
B10	APC ROY (C.E.) BUILDING	0.7	2.2499	466.2	734.23	0.000390702
B11	AURBINDO BOY'S HOSTEL	0.7	2.2499	529.92	834.58	0.000444102
B12	SATYAN BOSE BOY'S HOSTEL	0.7	2.2499	939.09	1479.00	0.00078701
B13	CHITTRANJAN BOY'S HOSTEL	0.7	2.2499	452.1	712.02	0.000378885
B14	MAIN BUILDING	0.7	2.2499	2087.05	3286.95	0.001749064
B15	CENTRAL LIBRARY	0.7	2.2499	344.44	542.46	0.00028866
B16	NIVEDITA GIRL'S HOSTEL	0.7	2.2499	552.62	870.33	0.000463126
B17	MOTHER TERESA GIRLS' HOSTEL	0.7	2.2499	441.89	695.94	0.000370328
B18	TEACHERS ENCLAVE	0.7	2.2499	530.69	835.79	0.000444748
B19	MULTI GYM	0.7	2.2499	193.06	304.05	0.000161795
B20	STUDIO APPARTMENT I	0.7	2.2499	166.4	262.06	0.000139452
B21	STUDIO APPARTMENT II	0.7	2.2499	172.8	272.14	0.000144816
				Total	15006.27	0.007985178

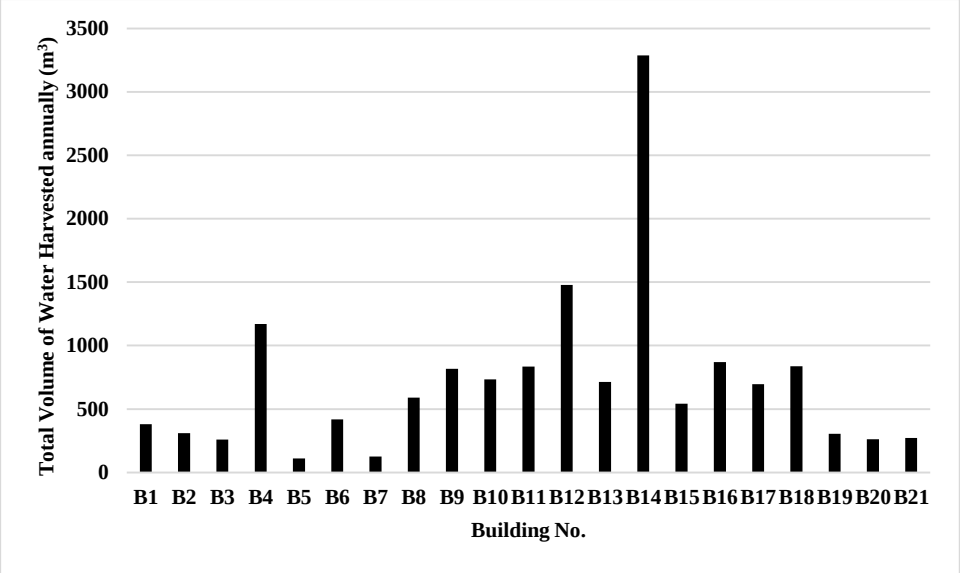

Figure 1 – Variation of annual water harvesting capacity for different buildings.

E. Estimation of monthly discharge

It is also important to estimate the amount of water in different months of the year. For this, rainfall depth for different months is multiplied with the total catchment area of different buildings in the campus. In table 6 estimated discharges over different months of the year is shown. From this table it is shown that total 21437.54 m^3 water is estimated to be harvested theoretically over a year. Considering runoff coefficient 0.7, actual amount of water that can be harvested in the year is (21437.54 x 0.7) m^3 = 15006.27 m3 ≈ 15 x 10^6 litre of water. In figure 2 the variation of estimated water over different months of the year is shown.

Table 6 – Estimation of monthly discharge.

Sl. No.	Month	Rainfall(mm)	Total Catchment Area (m^2)	Discharge(m^3)
1	January	24.7	9528.22	235.347034
2	February	11.4	9528.22	108.621708
3	March	45.9	9528.22	437.345298
4	April	112.1	9528.22	1068.113462
5	May	182.6	9528.22	1739.852972
6	June	238.5	9528.22	2272.48047
7	July	336.5	9528.22	3206.24603
8	August	369.8	9528.22	3523.535756
9	September	511	9528.22	4868.92042
10	October	401.5	9528.22	3825.58033
11	November	8.7	9528.22	82.895514
12	December	7.2	9528.22	68.603184
	TOTAL	2249.9	114338.64	21437.54218

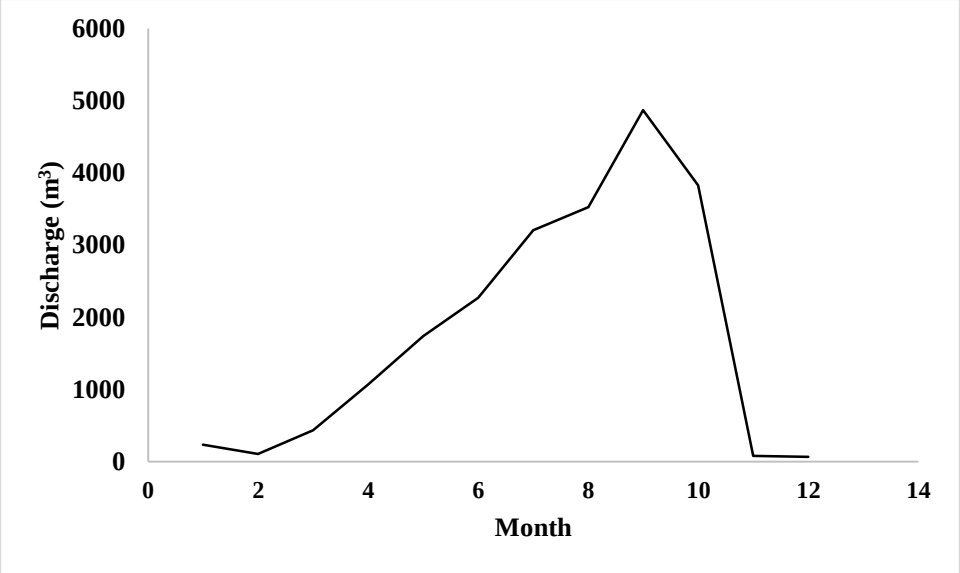

Figure 2 – Variation of monthly water harvesting capacity of BCREC campus.

In table 7 the detailed analysis of water harvesting capacity of BCREC campus is tabulated and shown.

Table 7: Harvesting Capacity Monthly Runoff (m^3)

		Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	TOTAL
Building No.	Area (m^2)	Rainfall (mm)	24.7	11.4	45.9	112.1	182.6	238.5	336.5	369.8	511	401.5	8.7	7.2	
B1	241.47		5.96	2.75	11.08	27.07	44.09	57.59	81.25	89.30	123.39	96.95	2.10	1.74	543.28
B2	196.98		4.87	2.25	9.04	22.08	35.97	46.98	66.28	72.84	100.66	79.09	1.71	1.42	443.19
B3	164.64		4.07	1.88	7.56	18.46	30.06	39.27	55.40	60.88	84.13	66.10	1.43	1.19	370.42
B4	742.08		18.33	8.46	34.06	83.19	135.5	176.9	249.7	274.42	379.20	297.95	6.46	5.34	1669.61
B5	69.18		1.71	0.79	3.18	7.76	12.63	16.50	23.28	25.58	35.35	27.78	0.60	0.50	155.65
B6	264.84		6.54	3.02	12.16	29.69	48.36	63.16	89.12	97.94	135.33	106.33	2.30	1.91	595.86
B7	78.96		1.95	0.90	3.62	8.85	14.42	18.83	26.57	29.20	40.35	31.70	0.69	0.57	177.65
B8	374.77		9.26	4.27	17.20	42.01	68.43	89.38	126.1	138.59	191.51	150.47	3.26	2.70	843.20
B9	519.04		12.82	5.92	23.82	58.18	94.78	123.7	174.6	191.94	265.23	208.39	4.52	3.74	1167.79
B10	466.2		11.52	5.31	21.40	52.26	85.13	111.1	156.8	172.40	238.23	187.18	4.06	3.36	1048.90
B11	529.92		13.09	6.04	24.32	59.40	96.76	126.4	178.3	195.96	270.79	212.76	4.61	3.82	1192.27
B12	939.09		23.20	10.71	43.10	105.3	171.5	223.9	316.0	347.28	479.87	377.04	8.17	6.76	2112.86
B13	452.1		11.17	5.15	20.75	50.68	82.55	107.8	152.1	167.19	231.02	181.52	3.93	3.26	1017.18
B14	2087.1		51.55	23.79	95.80	233.9	381.1	497.7	702.3	771.79	1066.48	837.95	18.16	15.03	4695.65
B15	344.44		8.51	3.93	15.81	38.61	62.89	82.15	115.9	127.37	176.01	138.29	3.00	2.48	774.96
B16	552.62		13.65	6.30	25.37	61.95	100.9	131.8	185.9	204.36	282.39	221.88	4.81	3.98	1243.34
B17	441.89		10.91	5.04	20.28	49.54	80.69	105.4	148.7	163.41	225.81	177.42	3.84	3.18	994.21
B18	530.69		13.11	6.05	24.36	59.49	96.90	126.6	178.6	196.25	271.18	213.07	4.62	3.82	1194.00
B19	193.06		4.77	2.20	8.86	21.64	35.25	46.04	64.96	71.39	98.65	77.51	1.68	1.39	434.37
B20	166.4		4.11	1.90	7.64	18.65	30.38	39.69	55.99	61.53	85.03	66.81	1.45	1.20	374.38
B21	172.8		4.27	1.97	7.93	19.37	31.55	41.21	58.15	63.90	88.30	69.38	1.50	1.24	388.78

3.RESULTS AND DISCUSSION

In the further study it is assumed that the harvested water is used to meet the daily requirements of residential parts of the campus. In this regards the harvested water is assumed to be supplied to the hostels and faculty quarters. In table 8 water requirement of the said buildings are calculated. Water requirement for each person per day is considered as 0.155 m3. From the table it is obtained that total 168.02 m^3 = 168 x 10^3 litre water is required per day to meet the water requirement of the residential parts of the campus.

Table 8 – Water requirement for residential parts of BCREC campus.

Sl. No.	Residential Buildings	Population (Number)	Water Requirement per day in m^3 per person	Total water requirement per day in m^3
1	AURBINDO BOY'S HOSTEL	200	0.155	31
2	SATYAN BOSE BOYS' HOSTEL	200	0.155	31
3	CHITTRANJAN BOY'S HOSTEL	200	0.155	31
4	NIVEDITA GIRL'S HOSTEL	200	0.155	31
5	MOTHER TERESA GIRLS' HOSTEL	200	0.155	31
6	TEACHERS ENCLAVE	24	0.155	3.72
7	STUDIO APPARTMENT I	20	0.155	3.1
8	STUDIO APPARTMENT II	40	0.155	6.2
	Total		Volume (m3)	168.02

A. Calculation of water harvesting potential

Water harvesting potential in terms of day is estimated as per the total amount of water requirement. Here in this study, Rapid Depletion Method is used to estimate no. of days potential. Monthly and total potential that is estimated is shown in table 9.

Table 9 – Water harvesting potential (in nos. of days) by Rapid Depletion Method.

Month	Water harvested (m3)	Water Harvesting potential in days
January	235.347034	1.40
February	108.621708	0.65
March	437.345298	2.60
April	1068.113462	6.36
May	1739.852972	10.36
June	2272.48047	13.53
July	3206.24603	19.08
August	3523.535756	20.97
September	4868.92042	28.98
October	3825.58033	22.77
November	82.895514	0.49
December	68.603184	0.41
	Total	127.59

4. CONCLUSION

In this study, all the aspect of improving the water scarcity problem in the BCREC, Fuljhore, Durgapur campus is dealt with by implementing ancient old technique of rainwater Harvesting. The results are given clearly in different tables.

- First bullet Hence from table 7, it may be concluded that a huge amount of water got collected from the rooftop surfaces of different buildings.
- If, this project is done seriously and implemented to the campus then the huge potential of Main Building and Hostel buildings may be effectively utilised. Main building alone can harvest almost 3.3 x 106 litre of water each year. This water can supply almost 20 days for the residential parts of the campus for almost 1100 nos. of consumers a rate of 155 litre/day as calculated by rapid depletion method.
- Total harvested water may be supplied to almost 1100 residents for 127 days in a year.
- Hence it was finally concluded that implementation of RAINWATER HARVESTING PROJECT to the campus of BCREC campus will be the best approach to fight with present scenario of water scarcity in all aspects, whether it is from financial point of view or from optimum utilization of land surface.
- Therefore, water is highly a precious natural resource which is always in high demand in the campus of BCREC Durgapur and thus, RAINWATER HARVESTING AT BCREC Durgapur campus is highly recommended.

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