Rain Water Harvesting For Economical Water Supply-A Case Study of Purulia Region

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Abstract - *The research work is basically focused in the applicability of rain water harvesting in the summer days in Purulia, an urban and water deficient district of west Bengal. As water is available throughout the year in this region therefore, rather than considering the demand & supply for the whole year, the 75 days of summer is chosen as the working period. The project aims to fulfill the purpose of toilet flushing, washing of clothes and washing of houses with the harvested water through a structured strategy. While the water for rest needs like drinking and cooking are fulfilled by the municipality water supply in every houses. Therefore with respect to mitigate the aforesaid needs within the summer days which is the focused working period the overall project is proved to be cost effective and useful for the lower section of people.*

The paper discusses about rainwater harvesting system in a typical 2 storied individual house each one a 3 BHK spread across an area of 60sqm.It also discusses rain water harvesting in the buildings with maximum possible utilization of land and also trying to implement the system in minimum possible per capita cost.

Key Words: **Cost effective, demand, Purulia, Rainwater harvesting, structured strategy, summer**

1. INTRODUCTION

About ninety seven (97) percent of global fresh water is ground water and it is economically viable source of potable water for more than half population of the world [1]. Rapid urbanization and industrialization has led to incessant withdrawal as well as pollution of Ground water in recent times [2]. As a result of it in spite of covering a large part of the earth, water is not free everywhere now-a-days [3]. Therefore even after crossing four years of the 'Decade of Water Life' (2005-2015) till today the supply of quality water is still an unconvinced promise to a huge section of world's population [4]. As per several studies, by 2025 all countries will face some sort of water hassle [5] which indicate that harmless, piped, community water will still not be available for all in future [6]. Therefore, it's time to think of all possible approaches that can be used to mitigate the deficiency of water. Individual RWH systems are one of the many tools to meeting the growing water demand [7]. RWH is a prehistoric technique which has been used from millennium in several older civilizations as in China, Israel etc [5, 8]. In this "soft path" approach rain water is being captured, sidetracked and being stored for further use but without draining off [9]. This is good policy towards a better future that ensures food security as well as reduces problems of water scarcity [5]. Most of the natural sources of water like rivers, ponds, lakes and ground water also depend on the rain to get feed [8]. On the other hand, along with being pure and soft rainwater has neutral pH [8]. Usually the people of water-scarce rural areas of developing countries used to harvest rainwater for their drinking and household purpose. But day by day with increasing surface and ground water contaminations it has also becomes relevant in areas with heavy rainfall also [6]. So, RWH has now become a global interest as an alternative source of water.

Such a potential study was made by Steffen et al 10] in U.S. They took 23 cities in seven climatic regions and during their study they found water-saving efficiency is a function of cistern size and climatic pattern. They actually found implementation of RWH as a storm water control measure could be very much beneficial for providing supplemental water. RWH is also not new in Zambia also. By selecting two of the water deficient periurban areas of Lusaka systems were designed by Handia et al [7]. For storage the basics were mass curve analysis and rational formula was chosen for the gutters. Developed countries like New Zealand, Australia, Germany, and Denmark also took this approach with the same importance and used it in private houses as well as in working sectors also [6]. Not only just harvesting but the improvement of the water quality is also very essential. A noble initiative of using foam and sand as dual media filter was made by Mishra et al [11]. This dual filter for roof water harvesting system could be used for any residential and commercial building. It was advised to use requisite amount of chlorine as disinfectant before use.

In India ground water recharge is very important in dry state like Rajasthan where ground water is the main source of drinking water and also for irrigation purpose [9]. So, each and every drop of rain water in these places can be proved life saving. Similarly in West Bengal there are many places which has very harsh climate and people starve there for water during the extreme hot summer.

Purulia is the driest and hottest place in West Bengal and one of the places in India [12]. Most rainfall occurs in monsoon but the summers are extremely dry with temperature rising as high as 50° Celsius. During summer seasons most of the surface as well as underground sources dry up leaving the region with an acute crisis of water leading to drought. The rainfall during the monsoon flows off due to the land form. So, we have chosen this arid area of west Bengal where we are looking forward to store the monsoon rain and use it during the dry summer most of the source of water dries up.

1.1 Study area

The area shown in the Fig.1 is chosen for the study. It is situated in the main town of the Purulia district. The location comes under the block Purulia-1. Its coordinates are 23.326744 latitude and 86.363474 longitudes. This is a resident building and is located in Baligara, near Purulia indoor stadium.

Rainfall occurs in the months of July to September. At present to cope up the existing demand of the water in this area is partially satisfied by pump house situated at a distance of 2 km, and buying water tankers for individual houses. This building 2 floors having a separate flat in each floor .Each flat is a 3 BHK spread across an area of 60sqm.

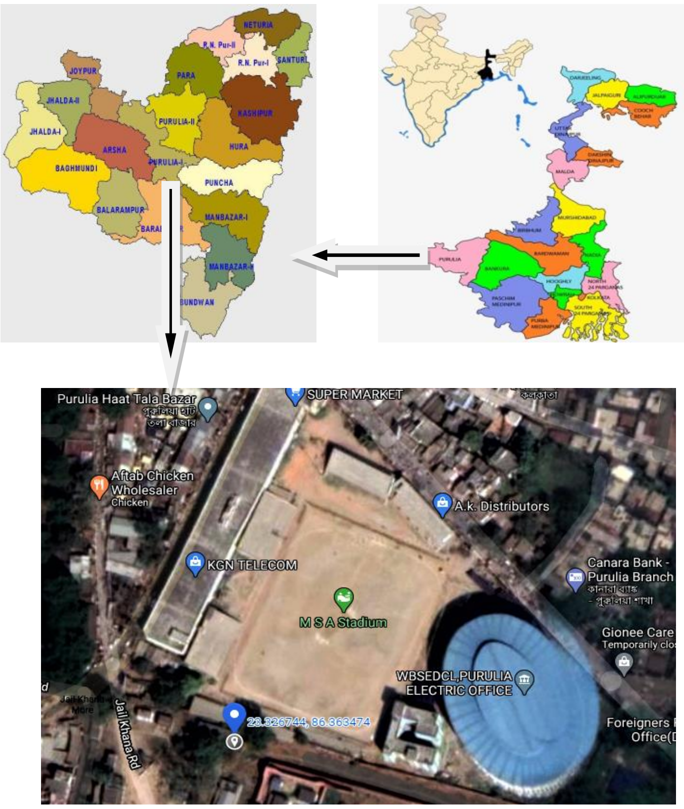

Fig.1. Location of the study area

2. MATERIALS & METHODOLOGY

This part basically depicts the main activities starting from the collection of rain water. In the first step rain water falling on the terrace is collected by providing proper slope through PVC down pipe during the 4 months of monsoon June to September. Then it is stored in an underground reservoir. In time (summer: March to May) of need the store water is pumped to an overhead tank and supplied to the demand area. The volume of the water collected by the below formula [13].

Q=kRA,
Where, R=Rainfall
A=Area of collection catchment
k= Run-off coefficient which is taken as 0.85 for concrete roof.

3. BASIC COMPONENTS OF THE SYSTEM

The system basically includes three basic components Catchment area is one of them which include roofs. The other one is the Storage unit that is concrete tank. The Mechanism which facilitates the transport of the water that falls into the storage unit is an important part of this section.

3.1 The structure

The structure is designed for 2 storied building each one a 3 BHK spread across an area of 60sqm or 645.835sqft. Under 645.835 sq.ft carpet area we may get,

Bedrooms - 1 nos x 120 sq.ft (12′0″ x 10′0″) = 120sq.2nos x 100 sq.ft (10’0”x 10’0”) =200 sq.ft.

Kitchen - 1 no x 72 sq.ft (8′0″ x 9′0″) = 72 sq.ft.

Toilets - 2 nos x 40.5 sq.ft (4′6″ x 9′0″) = 81 sq.ft.

Living/Dinning- 1no (10′0″x16′0″) =160sq.ft.

In this way the no. of floor obtained is G+1 (two). The no. of resident per floor, total population & roof are 6, 12 & 633 Sft or 58.81 Sqm respectively.

4. RAINFALL DATA

The rainfall data of Purulia from the year 2010 to 2019 is recorded & tabulated in Table.1

Table -1: Ten years rainfall record of Purulia (2010-2019)

YEAR	TOTAL (mm)	MONSOON (mm)
2010	1466.72	1330.12
2011	1662.06	1493.49
2012	1330.22	1141.89
2013	1643.80	1265.43
2014	1271.40	1111.30
2015	1275.26	1072.63
2016	1375.29	1181.99
2017	1454.57	1248.35
2018	1289.45	1120.54
2019	1872.34	1649.24

Table -2: Volume of water required for domestic purpose

PURPOSE	WATER REQUIRED PER DAY(L)
Toilet flushing	30
House washing	10
Cloth washing	20
Utensils' Washing	10
Cooking	5
Drinking	5
Bathing	55
Total	135

5. PER CAPITA USE OF WATER

Water is the most important resource required for the sustainability of life. Not only humans but also for the survival of all other living beings water is the most essential thing. From our daily house hold purposes to industrial as well as in agricultural needs also water is a must. The requirement of water for different household needs is called Domestic water use [14]. The total volume of water required for domestic purpose is shown categorically in table. 2. The amount of water required for every individual varies from person to person place to place. The standard norms for domestic water usage in India is 135 liters per capita per day (lpcd), prescribed by Central Public Health and Enviromental Engineering Organistaion **[15]**.A studyfound that 50% of domestic consumers use less than 90 lpcd [16].

For domestic purpose we require water both portable and non portable water. To obtain portable water from rainwater is a bit expensive as it requires filtration of the water before consuming it. In Purulia the requirement of drinking and cooking is somehow met with by the water supplied by the local bodies. But there are demands for water purposes which require a large amount of water and cannot be met by public supply scheme. Toilet flushing and washing of house is one of major requirement of large volume of water and it can be compensated by the valuable available portable water. So in order to have reserve water for these very purposes we will design the Rainwater harvesting system. So the system will collect and store the monsoon rain and use it during the dry summer seasons for the non portable use for the purpose of Toilet Flushing, Washing of House, and Washing of Clothes hence saving the valuable portable water for major uses. The bar diagram of per capita domestic use of water is shown in along with Table. 2.

5.1 Volume of water required for system

Purulia is a place where people have to face water scarcity basically in the summer season. In this season all lakes dries due to high temperature and underground level of water also falls down. But other than this season water is available throughout the year. Even in summer season also government has given drinking water connections in every house. Therefore the system is designed to fulfill the only need left here is water for toilet, washing and bathing in summer season for two and a half months (75 days). The total population of the proposed 2storeyed building is considered as 12 (2×6). The main three purposes of water requirement are toilet flushing, washing of house and cloth washing. Now if the amount of water required for these three consecutive domestic purposes follows the amount of 30L, 10L, and 20L respectively the total requirement of water becomes 60L.Therefore the volume of water required per person for two and a half months in summer season = (60×75) = 4500.00LHence volume of water required for the system once entire population proposed building = (4500.00×12) =54000L or 54 Cum.

5.2 Probability of rainfall occurrence

Rainfall and other natural phenomenon can't be determined beforehand but by using different methods we can at least guess and estimate the nature of forthcoming rainfall.

By using the record data of last 13 years we can estimate the probability of reoccurrence of the corresponding rainfall. The probability is determined by the following formula

$$\frac{n}{N+1} \times 100$$

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Where; n=tabular position of data and N=total number of data.

As we know the maximum recorded precipitation has the least probability so in order to select the amount of rainfall for our further study the rainfall data is firstly arranged in descending order which is shown in Table. 3.

Table -3: Probability of reoccurrence of rainfall

SL.NO	YEAR	MONSOON AVERAGE	DECENDING ORDER	PROBABILITY
1	2010	332.53	412.31	9.09
2	2011	373.37	373.37	18.18
3	2012	285.47	332.53	27.27
4	2013	316.36	316.36	36.36
5	2014	277.83	312.09	45.45
6	2015	268.16	295.50	54.55
7	2016	295.50	285.47	63.64
8	2017	312.09	280.14	72.73
9	2018	280.14	277.83	81.82
10	2019	412.31	268.16	90.91

By the formula Q=kRA, the probability of each average monsoon rainfall is calculated. It can't be guaranteed but it can be at least expected to have the future trend of rainfall according to the assumed probability. For further calculations and carrying out designing of the rainwater harvesting system three probabilities and their corresponding rainfall is considered. When the Probability is 54.55% then Rainfall becomes 295.50mm. Whereas For the probabilities 72.73% & 90.91% the amount of the rainfalls become 280.14 mm & 268.16 mm respectively. Now by considering three different cases of probability of occurrences we can get a detailed picture of how fruitful our study is going to be.

CASE 1: For 54.55% Probability of occurrence

The total demand of water from the system is 54 Cum.

Collection of Rainfall: In case of Average rainfall=295.50 mm, area of the Roof=60 sqm, run-off coefficient=0.85. The volume of rainfall collected according to the formula Q=kRA is Q= (0.85×0.295×60) =15.05 Cum.

Therefore the volume of rainfall collected for the entire monsoon season is (15.05×4) =60.2 Cum. So, very clearly the collected rainfall is more than the demand. The surplus volume of rainfall is (60.2-54) =6.2 Cum. This surplus volume of water can be used for more 8 days for the purpose of toilet flushing, washing house and washing clothes.

CASE 2: For 72.73% Probability of occurrence

The total demand of water from the system is 54Cum.

Collection of Rainfall: Now for the average rainfall=280.14 mm, roof area =60 sqm & the run-off coefficient=0.85, the volume of rainfall collected according to the formula Q=kRA is Q= (0.85×0.280×60) =14.28 Cum

Therefore the volume of rainfall collected for the entire monsoon season is (14.28×4) =57.12 Cum. Here also, the collected rainfall is more than the demand. The surplus volume of rainfall is (57.12-54) =3.12 Cum. The surplus volume of water can either be used for more 4 day for the purpose of toilet flushing, washing house and washing clothes.

CASE 3: For 90.91% Probability of occurrence

The total demand of water from the system is 54Cum.

Collection of Rainfall: For an average rainfall=268.16 mm, roof area =60 sqm & run-off coefficient=0.85, the volume of rainfall collected according to the formula Q=kRA is Q= (0.85×0.268×60) =13.67 Cum

Therefore the volume of rainfall collected for the entire monsoon season is (13.67×4)=54.68 Cum. The collected rainfall is more than the demand. The surplus volume of rainfall is (54.68-54) =0.68 Cum. The surplus volume of water can be used for more 1 day for the purpose of toilet flushing, washing house and washing clothes.

6. FEASIBILITY

We can see that the amount of rainfall collected is more than the demand for two out of three selected probability of occurrence. So in order to check whether it will be feasible to store the water so that it can fulfill the demand for the required period of time we need to carry out a graphical study for different probability and its corresponding rain fall.

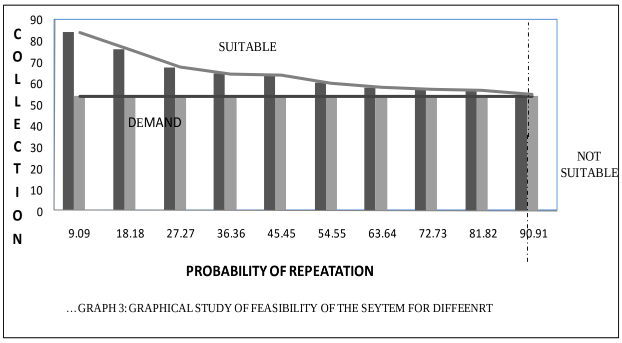

Chart -1: Graphical studies of feasibility of the system for different probability & its correspondent rainfall

From Chart- 1 we found that the volume collected is more than the demand in most of the probabilities. So the collected water can be easily used to fulfill the demand during the time of need. As it is satisfying the demand of maximum probabilities so, it is feasible to design a tank for storage of the collected water through the rain water harvesting system. The tank must be designed for the capacity more than the demand. There also must be proper man hole and other cleaning arrangement. The tank must also have a over flow system in order to drain the overflowing water to a proper ground water system. For the assumed rain fall the Rainwater Harvesting system is sufficient to supply water for the targeted use for the summer season.

7. TANK DESIGN

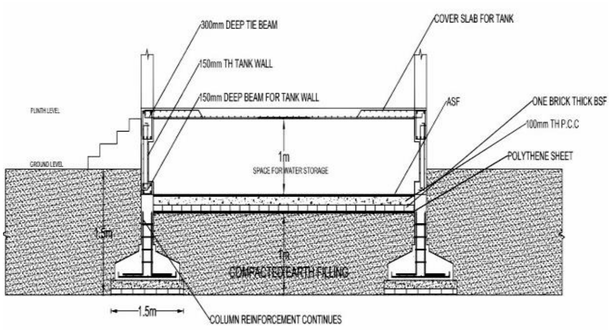

Fig.1. Rain Water Harvesting (RWH) tank

For middle class families land is a very useful and expensive resource. The tank must be sufficient to store water more than the demand. So a huge area of land is required to store the collected rainwater. So meet this challenge the entire area of the building 60.00 Sqm is used to construct the storage tank. The entire area of the building is used as a basement type structure of **1m depth** and a storage tank of 60.00Cum is obtained.

The total cost of the tank stands to **Rs 1, 52, 786.24 (excluding taxes).** The figure here is the amount which is additional to the cost of the building. Rest all other expenses in the tank are included in the cost of the building cost estimation of the tank as per PWD schedule is shown in Table. 4.

Table -4: Cost estimate of tank as per PWD schedule 16-17

Sl.no	Description	Unit	Qnty	Rate (Rs)	Amount (Rs)
1	Cement Concrete for R.C.C	Cum	12.15	5328.96	64746.86
2	Shuttering	Sqm	98.40	205.00	20172.00
3	Reinforcemnt	MT	1.22	5562	67867.38

7.1 Limitations

Nothing in the world is perfect and has some or other limitations, so is the system there are also some limitation but that can be removed or to be better minimized by further study. Here in this system the amount of water collected through it can be increased by increasing the area of receiving rainfall, but to decrease the unit cost of the building the design must be to accommodate more individuals. By further study on cheaper way of water purifying even Portable water need can be supplied. The storage time of the water is high so the water needs to be prevented from entry to dirt and small animals. The foundation and columns will stay in contact of water so proper water proofing must be done. So, these are some limitations associated with the system including helpful remedies.

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8. CONCLUSION

After doing the study we found that how useful a Rainwater Harvesting system can be to solve the problem of water in dry place like Purulia. The almighty has blessed Purulia with rainfall but the land form and climate can't just hold it on. By using the knowledge of engineering we may provide an alternate source to meet and diminish the scarcity of water as discussed in this work. From the study two conclusions could be made. One of them is rain water if collected on the roof catchment area of 60 sqm then it can sustain the demand to fulfill the requirement for Flushing, House Cleaning and Washing Clothes for 2.5 months (March to Mid-May) & the other one contains the service of extra water for more duration. Hence if we consider the **economy** of the system then we are utilizing the same area used by the building for making the tank hence we are saving a handsome amount of money and valuable land. The **total cost** of the tank is **Rs 1, 52,787,** but it stands only **Rs12, 732 per person** which is very small amount in return of water which we get for the entire serviceability of the building. Hence the system is economical and cost effective.

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