Planning strategies for Rooftop Rainwater Harvesting as potable water source in Churu City, Rajasthan

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Abstract- *The aim of this study is to find out the potential of Churu city to harvest rainwater using roofs of houses as catchment area. Churu is a part of Thar desert with rainfall variation of 400-600mm annually in months of June-September, rest months have only nominal or zero rainfall with net collectable rain of 400mm. Water supplied to the city is 69LPCD against urban demand of 90LPCD, which is mix of treated canal water and primary treated Ground water which is contaminated with fluoride, nitrate and salinity, sets demand of 100% potable water. In the analysis, it was found that rainwater has the potential to satisfy potable water demand of city. Residential area of city and potable water demand of residential area only is considered for this research.*

Keywords- Roof top Rainwater, water supply, scarcity

I. INTRODUCTION

According to Public Health Engineering Department of Churu, water supplied to Churu is 14MLD, 80% for domestic supply, out of which 15% lost in water distribution. So, waste available to public is 9.52MLD which is 700LPCD for 136500 people in year 2016. demand of a person per day is 100LPCD. 30% of demand and supply gap is noticed in Churu. In Churu, ground water level varies between 50-54m also water is contaminated with fluoride (1.5-3mg/l), nitrate (>100mg/l), salinity (>7000µS/cm) and high hardness as per Central Ground Water Board data. Surface water is not available as no natural river system is available in Churu district. Clean treated water is 4MLD available but it is supplied to people after mixing with ground water as unable to maintain pressure alone as per AMRUT report 2016, which sets 100% scarcity of potable clean water. Soil available is of alluvium nature which form fine to gravel and provides an impermeable or very low permeable nature of ground and thickness is of 100m. Rainfall received by Churu is only for 3-4 months only (June to September), rest of the months varies between 0-25mm and average annual rainfall varies between 400-600mm as per data of Meteorological Department of India. Out of 1032 Ha of developed area, 632Ha area is under residential Landuse in city and out of which 65% is dedicated to residential activity and rest to other Landuse and 66% built up on average houses. With net collectable rainfall of 400mm, 632ML (632X10000X 0.65X0.55X 0.4X0.7) is available from all plot roofs.

Table 1. Surface runoff potential of city

2016	Area (ha)	unbuilt	rainfall	runoff ML
Residential	632	0.45	0.4	1138
residential plot	632	0.35	0.4	885
commercial	27.6	0.6	0.4	66
industrial	28	0.6	0.4	67
state buildings	24	0.5	0.4	48
recreational	20	1	0.4	80
PSP	132	0.5	0.4	264
transport	112	1	0.4	448
Water body	4.85	1	0.4	19
total				3015

Collection of runoff storm water is with 20%, rest all will loss in evaporation, transpiration, infiltration etc. 603Ml of water is available at city level from surface runoff. Rainwater through open drains of waste water collected in low lying areas of city which are polluted by solid waste disposal along with zero maintenance. Therefore, rainwater gets polluted from both roofs and unbuilt impermeable areas and not available to use by common people. Due to slope of city from south-north, rainwater has the tendency to flow under gravity on the periphery of city where it gets collect in depressions. 632ML of fresh water in an area with potable water scarcity is going waste, with proper planning and strategies this quantity can be collected and utilized to support potable water demand of city.

II. WHAT IS ROOFTOP RAINWATER HARVESTING ?

Roof Rainwater harvesting refers to direct collection of precipitation fall on the roof without passsing through the stage of surface runoff on land [1]. Rainwater harvesting via

roof top and ground catchments is an ancient technique of providing domestic supply[2]. Rainwtaer collected by harvesting can be used for domestic purposes or landscape depends on the charaterstics of catchment. Rainwater is the only source which is easy to obtain individually and with minimum cost. Rainwater is usually free from physical and chemical contaminants such as pesticides, lead, and arsenic, color and suspended materials and it is low in salt and hardness[3]. Negev desert of Israel (250mm) with rainwater harvesting vegetation and landscaping took place[4]. The main advantage of Rooftop Rainwater Harvesting is it provide water source at the household level, decreasing the pressure of walking long distances to get water. The quality and quantity of water supplied to people is important aspect of domestic supplies as it influence the health of public[5]. It will help to reduce the burden on municipal water system that in general is always inadequate to meet needs of each and every household[6].

III. HISTORICAL CONTEXT OF ROOFTOP RAINWATER HARVESTING

From the various studies it has been concluded that Rooftop Rainwater harvesting is practiced globally to get potable water. As per the Rainwater harvesting report of Rajiv Gandhi National drinking mission, Barmer & Jaiselmer (Rajasthan) with 100-500mm rainfall. Due to scarce water source, saline nature, sandy soil. Poor drainage system problem of water is more acute. Rooftop rainwater harvesting adopted at household level, community level and institutions level with 10000-6,00,000L & 22000L at community and individual level water storage tanks. These tanks are adequate to meet demand of 6 family members @10LPCD throughout the year. In the same manner cases of rooftop harvesting found in Jodhpur and Churu also, even ancient forts have rainwater collection system from roofs in form of ponds or underground large tanks.

Therefore, as a solution to problem of potable water shortage traditional practice of rooftop rainwater harvesting is adopted.

Objective

The general objective of this study is to analyze the rooftop rainwater harvesting potential of city and its implementation at household level.

IV. METHODOLOGY

To achieve the desired aim, primary and secondary data are collected from various sources to know about the potential of study area on rooftop rain water harvesting by means of various parameters such as status of structures, roofs, tanks availability in house, affordability of people. Residential scheme was analyzed to know the roof area available in a residential area. As study area is a part of desert area of Rajasthan where rainfall is less, therefore total demand of household is not possible to meet with the rainwater only. But city require as much clean water it can get therefore storage of maximum water which falls on rooftop is required to meet potable demand form this water and rest from other sources. Rainwater stored is mainly use for drinking and cooking purposes in the dry period of the year. Secondary data like rainfall data collected from Meteorological Department of India.

To calculate amount of water from catchment, formula is used

$$Q=CIA$$

Q is quantity of rainwater available cubic meter per year
C is runoff coefficient
I is the intensity of rainfall in meter per year
A is the catchment area in square meter.

V. Status of Rainwater Harvesting in Churu City

Presently, rainwater is flowing on streets through open drains coming out form various Landuse to areas which are not well maintained and due to improper management of waste water and solid waste water is getting pollute which make it unfit for any type of use. Structures of ancient time are available in City which were then used for collecting rainwater for the public use but due to advent of water supply these structures are forgotten by people and communities. As Churu city has 76.3% open drains with no separate drains for storm water is get mixed with all type of impurities i.e. solid waste, waste from streets, animals etc. which make the fresh water pollute. As is the present scenery, rainwater is available to pollute by all external forces or pollutants available in city.

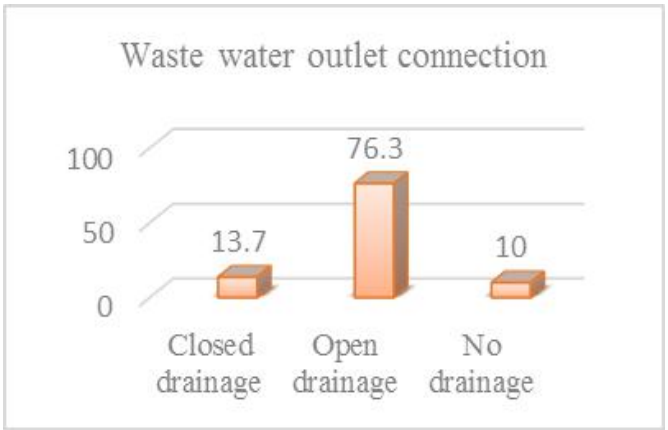

Figure 1. Waste water drains in City

there are of 10 principles in the usage and design and operational of material handling systems like Planning, standardization, work, ergonomics, unit loads, space utilization, systems, environment, Automation and life cycles. But much of the focus is laid in the present study is Automation and the planning. Rainwater harvesting structures of City which were source of fresh water but due to negligence and non-maintenance of structures leads their water unfit for use. Sethani ka Johad is located 2.5Km away from the settlement therefore pollutant like waste water, solid waste etc. are not affecting quality of water, also due to local authorities, development around the body is also not taking place but due to poor catchment surface water is of low quality. It happened because communities given up their role to government and when water is available through taps why one will travel to fetch water from these structures. Other structure which were common at household and community level were Kunds, structures are too out of fashion now left behind them with uncleaned tank and catchment area, unwanted vegetation which affects the quality of water. During the study of area, it was observed that people are again accepting the ancient methods to fetch potable water but now they are doing it at individual plot level. As people are adopting rainwater harvesting and collecting fresh water to complete their potable demand but very less in number. In the primary data, it was revealed that about 11% of houses are doing Rooftop Rainwater Harvesting in City and other are lacking due to various factors like less roof size, tank availability, affordability are the highlighted reason.

Low Lying areas

Setahni ka Johad Kunds

Figure 2.

II. ANALYSIS OF DATA

1. Rainfall analysis

Churu city is blessed with good rainfall between 400-600mm in 4 months mid-June to mid-September (Meteorological dept. Of India) and for the rest of the months rainfall is nominal in nature. For the analysis of rainfall, data from 1998-2016 is analyzed to know the net collectable rainfall available in Churu city. As rainfall occur with different intensity on different days which needs few mm of rainfall in first flush decrease the gross rainfall.

Table 2. Annual Rainfall data (1998-2016)

MONTH	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC	TOTAL
1998	0	12	6	7	0	62	84	87	187	201	4	0	650
1999	9	0	1	0	48	19	85	60	4	0	0	0	226
2000	0	0	0	0	25	8	131	37	28	0	1	0	230
2001	9	0	0	14	59	73	179	79	0	0	0	0	413
2002	6	0	4	5	64	71	18	109	0	0	0	11	288
2003	10	15	2	0	30	21	356	110	26	0	0	0	570
2004	7	0	0	6	17	10	115	45	53	0	0	0	253
2005	4	71	48	25	40	106	75	6	69	0	0	0	444
2006	0	0	20	0	63	56	148	26	11	12	3	2	341
2007	0	45	40	4	19	60	34	126	121	0	0	0	449
2008	0	0	0	22	75	149	88	224	78	0	0	0	636
2009	0	15	20	9	52	88	90	125	70	4	1	1	409
2010	4	4	4	1	1	68	132	195	172	0	14	20	614
2011	0	14	8	5	38	182	103	191	111	0	0	0	651
2012	1	0	0	18	26	0	104	230	43	2	0	5	430
2013	29	33	3	4	1	32	162	141	48	7	9	0	468
2014	7	17	23	15	54	46	170	57	92	1	0	0	481
2015	4	2	64	55	23	48	214	116	9	2	0	0	536
2016	0	21	11	3	39	214	98	141	121	0	0	0	648
AVERAGE	6	12	16	14	25	84	141	153	85	2	3	4	547

Source: Meteorological Department of India

After considering the first flush losses upto 4mm per rain, net collectable average rainfall is 400mm per year. Four months constitute the main part of annual rainfall and rest months are dry. So, planning is required for these four months to meet the requirement of rest of the year. For the design of system 400mm annual rainfall should be considered.

2. Physical survey and collection of data

3. Neighborhood analysis

4. Plot Size Distribution

By using results of primary survey and analysis of neighborhood, different size of roof areas calculated. Proportion of each category is calculated at city level on the basis of results:

Table 3. Proportion of various plot size

PLOT SIZE M²	% SHARE	% PLOTS (22460)
<50	25	5524
50-100	33	7764
100-162	19	4360
162-225	12	2354
225-350	7	1579
>350	4	879

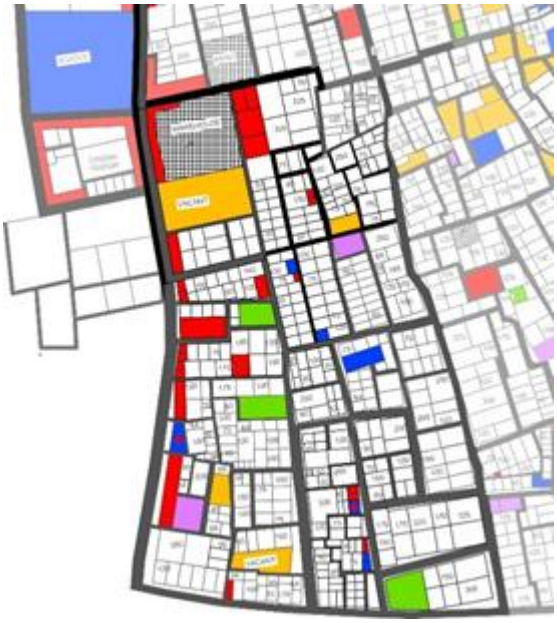

Figure 3. Ward No. 28

Table 4. Land under different Landuse

Roads	22.90%
Commercial	7.6%
Institutional	6.9%
Religious	0.61%
Park	2.16%
Open space	0.21%
Vacant	4.60%
Residential	55.02%
Total	100%

- Household size

Table 5. household size as per number of plots

No. of plots	416	Year
Population	2613	2011
	2887	2016
Average	6.9	

From neighborhood survey, average household size is 6.9. Form the primary data, 167 houses were surveyed and number of people living were tabulated as:

Table 6. household size as per survey

SIZE	TOTAL	EWS+LIG	MIG	HIG
Plot size (sqm)		<50	50-225	>225
1	2	3	4	5
Households	167	44	96	27
1	2	1	1	0
2	8	4	4	0
3	19	7	7	5
4	38	10	22	6
5	34	9	22	2
7	45	11	29	6
10	21	1	12	7

Form the weighted mean, average household size comes out is 5.5. as per the census of India 2011,

Table 7. Household size as per Census data

SIZE	TOTAL	EWS+LIG	MIG	HIG
Households	18116	2577	12507	3032
1	217	84	114	19
2	730	257	417	56
3	1190	317	775	98
4	3066	590	2180	296
5	3581	586	2590	405
6-8 (7)	6301	658	4692	951
9+ (10)	3031	85	1739	1207
Average	Σ Size X Total			6.01

Average household size comes out is 6. Therefore, due to the limitation of small sample size which may not resemble whole city therefore average household size is taken as 6.

Average Built-up

Different plot size available in the city has different ground coverage which gives different size of roofs. So, to identify total area of catchment, built up of different plot size is calculated.

Table 8. Plot size and ground coverage

PLOT SIZE M²	AVERAGE SIZE M²	AVERAGE BUILTP %
<50	36-	90
50-100	75	76
100-162	125	68
162-225	175	60
225-350	285	50
>350	425	49

Average built up of different plot size by using their proportion of occurrence in city weighted average mean which can be used for whole city find out as 66.5%.

Housing structure

Total number of household as per the Master Plan 2031 and Census of India 2011 in 2011 was 19238 & according to latest report of AMRUT, WAPCOS in 2016 is 22460. As per the physical survey of Churu only 0.5% of total residential area is dedicated to Group Housing (Civil Lines and Police housing) and rest all is plotted development i.e. 99.5%. Therefore, project only took into consideration and planning for plotted development only. Churu city is an ancient settlement in which ancient houses more than 40 years, stone roofs and walls found in old settlement part of Churu which is present around the Clocktower of Churu and ancient Fort. Almost 70ha of area is dedicated to these ancient structures in Churu and rest other is new settlement which is develop ed using mainly RCC as their construction material. Stone roofs are also favorable to collection of rainwater as they also provide impermeable surface but with less efficiency than RCC roofs. Roofs of these structures are flat in nature with slope <10% which are adequate to provide nominal slope to provide passage to water through pipes.

Figure 4.

Roof material

As per the census of India, 2011, and primary data, roofs are made up of different materials which act as catchment for rainwater collection. Different roof materials play important role in the quality and quantity of rainwater collected. Permanent houses-bricks, lime and stone and RBC/RCC concrete are used for roof, Semi Permanent: Semi permanent houses refer to those houses made of other types of materials. Temporary: houses having wall and roofs made of Kutcha materials, i.e., where, grass, leaves, mud and unburnt, wood.

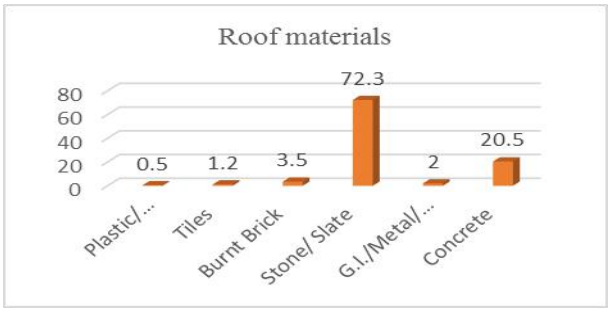

Figure 5. Proportion of house with different roof material

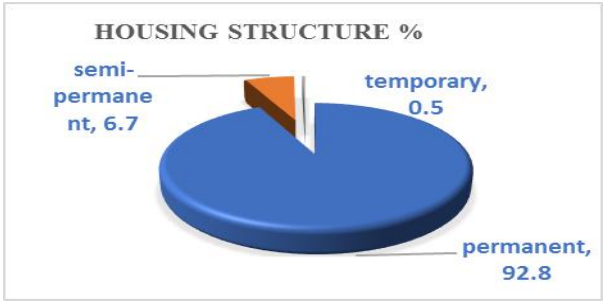

Figure 6. Proportion as per structure.

92.8% of roofs are made up of stone and RCC, which provides an impervious surface. Average runoff coefficient is 0.8 for stone and RCC roof.

i. Water supply status

Churu city gets water from two source: ground water and surface water (Indira Gandhi Canal flows 129km North-West of city). Water supplied from IGC is 4MLD and from groundwater is 9.9MLD but water available underground is limited to 7.01MLD extraction as per Ground water year book 2014-15. 80% of total water supply is supplied for domestic purpose and rest is for other activities of city like commercial etc.

Table 9. Water supply status

Year	Daily domestic demand @100lpcd	PHED total supply	GW	IGNP	DOMESTIC SUPPLY 80%	AVERAGE PER CAPITA DEMAND LPCD	TRANSMISISION LOSSES (GUIDELINES ON WATER NETWORK SYSTEM)	PER CAPITA WATER SUPPLY
2016	13.650 MLD	14 MLD	9.91MLD (71.2%)	4 MLD (28.8%)	11.133 MLD	90 LPCD	15%	69 LPCD (69%)

This shows 24% of gap in demand and supply and water supplied to the Churu City is by mixing ground water and treated water from Indira Gandhi Canal to maintain the pressure in network. Ground water after primary treatment is mixed with treated water but chemical contamination is not fully removed from water. It creates demand of 100% clean water so that clean potable water can be supplied to network.

VII. RESULTS AND DISCUSSION

Total water available from different plot size all over the city gives the water available to fulfill the demand of city. Quantity of rainfall from a roof size= amount of rainfall X runoff coefficient X roof area

Table 10. showing quantity of water from different plot size per month

MONTHS	DAYS	2010	2011	2012	2013	2014	2015	2016	AVERAGE MONTHLY RAINFALL MM	AFTER FIRST FLUSH MM	QUANTITY= ROOF AREAX RAINFALLXRUNOFF COEFFICIENT X1000 (L)					
											<50	50-100	100-162	162-225	225-350	>350
									Build up		90%	76%	68%	60%	50%	49%
									1	2	3	4	5	6	7	8
JUNE	30	68	182	0	32	46	48	214	84	60	1555	2736	4493	5760	6816	7644
JULY	31	132	103	104	162	170	214	98	141	125	3240	5700	9360	12000	14200	15925
AUGUST	31	195	191	230	141	57	116	141	153	121	3136	5518	9060	11616	13746	15415
SEPT	30	172	111	43	48	92	9	121	85	66	1711	3010	4942	6336	7498	8408
OCT	31	0	0	2	7	1	2	0	2	0	0	0	0	0	0	0
NOV	30	14	0	0	9	0	0	0	3	0	0	0	0	0	0	0
DEC	31	20	0	5	0	0	0	0	4	0	0	0	0	0	0	0
JAN	31	4	0	1	29	7	4	0	6	0	0	0	0	0	0	0
FEB	28	4	14	0	33	17	2	21	13	0	0	0	0	0	0	0
MARCH	31	4	8	0	3	23	64	11	16	8	207	365	599	768	909	1019
APRIL	30	1	5	18	4	15	55	3	14	7	181	319	524	672	795	892
MAY	31	1	38	26	1	54	23	39	26	18	467	821	1348	1728	2045	2293
TOTAL	365	614	651	430	468	481	536	648	547	405	10498	18468	30326	38880	46008	51597

Table above clearly showing potential of different rooftop, considering the average built up of plot, runoff coefficient of roof material, first flush losses. Each plot size potential if multiplied with number of houses available in Churu city give the true potential of whole city.

As per the Indian Standard IS 10500:2004, water demand per capita for drinking and cooking is 10LPCD. To check the potential of Churu city to support the potable water demand, total potable water demand is required to calculate as Total potable water demand= Population X per capita demand X 365

Table 11. Calculation of Total rain water and total water demand of city

PLOT SIZE	<50	50-100	100-162	162-225	225-350	>350	TOTAL
ECONOMIC CLASSIFICATION	EWS+LIG	MIG			HIG		
PROPORTION	18.8/25	32/33	19	12	7	4	42
NO. OF PLOTS	4222	7187	4267	2695	1572	898	20843
TANK KL	4	4	8	8	8	8	
RAINWATER PER PLOT PER YEAR	10498	18468	30326	38880	46008	51597	
TOTAL WATER ML PER YEAR	44	133	129	105	72	46	530
DEMAND LPCD	10	10	10	10	10	10	
TOTAL DEMAND ML				136500X10X365			498
WATER IN EXCESS ML							32

Plot size <50sqm and 50-100sqm consists of houses which do not have impermeable roof material, therefore proportion of houses decrease from 25 to 18.8 and 33 to 33 respectively. It is analyzed that city in which clean water is not available to drink and rainfall of sufficient quantity is available, rainwater harvesting can support the present scenario fully. As 530 million liters of water is available from roofs and annual potable water demand is 498 million liters which is less than available. So, rooftop rainwater harvesting is feasible in present scenario and should be implement at each house to get maximum benefit from it.

VIII. RECOMMENDATIONS

Byelaws in context to Churu city should have inclusive policy to implement the Rooftop Rainwater harvesting at household level, it is to advise/ recommend to store rainwater at individual household level this will provide a qualitative source of potable water at residents as per guidelines recommended below:

- To store rooftop rainwater at plot level, it may be mandatory to construct at least 4KL & 8KL on <100sqm and >100sqm respectively.
- Front setbacks of houses in City are not as per byelaws which is limitation in constructing water tank on plots therefore Setbacks of at least 1.5m on plot size <100sqm and 3m on plot size >100sqm should be made mandatory for new development.
- It is recommended for Owner to deposit caution money of Rs 10,000 for plot size <100sqm and Rs 20,000 for >100sqm and after construction of underground water tank, it should be refunded to the owner, or if owner does not construct underground water tank then it should be used for the underground community tanks construction.
- Liberal approach in form of subsidy under Swatch Bharat Mission and from local authorities should be worked out to encourage local people to construct underground water tanks.
- Subsidies can be provided from the expenditure saved from the benefits of decrease in extraction, treatment cost, pumping cost, network cost, water losses cost etc. encourage adoption of rooftop rainwater harvesting.

IX. CONCLUSION

Churu city located in hot and semi-arid climate, suffering from 100% potable water scarcity. City has potential to cater problem 100% by Rooftop Rainwater collection system which is more effective than conventional system of RWH. As Rainwater harvesting system provide economic source of fresh water at house level under owner jurisdiction. Quality of rainwater is good and treatment of nominal nature is required before use. Negative effects on health due to contaminated water eliminate fully. Decrease in pressure and cost on government authorities of extraction, Water treatment plant operational capacity and supply of water. Source of water is not available to exploit by external factors like solid waste, waste water, other people etc. Adoption of traditional methods for completing demands which declares success of this project as it is already practiced in city but very less. So, it is of utmost importance to implement this type of projects immediately and effectively in place like Churu with adverse climatic condition to make it self-sustain for potable water for now and for the years to come.

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