Management of Scarce Water Sources using Rooftop Rainwater Harvesting in Churu City, Rajasthan

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Abstract— The aim of this study is to provide a solution for the management of various water source available in city to meet the domestic water demand. Rainwater as an alternate source to meet potable water demand of city. Churu lies in hot and semi-arid region of Rajasthan with temperature variation of -2°C- 50°C with annual rainfall between 400-600mm annually. Water supplied to the city is 69LPCD against demand of 90LPCD with scarcity of potable water 100% due to contamination of water with fluoride, nitrate and salinity. Groundwater table is dropping continuously from 1984 (35m), 2010 (40m), 2010 (45-50m), 2015 (50-54m). As a solution to these problems, this research explores, Rooftop Rainwater Harvesting (RRWH) as source of clean water at household level and community level for potable uses. This paper deals the challenge of providing clean water to people by using rain as clean source of water and management of different water sources to check their exploitation in Churu City.

Key words: Rainwater Harvesting, Tanks, Potable Water Demand, Management

I. INTRODUCTION

Domestic water supply of Churu supplied by main source of water is ground water 71.25% of water extracted form and rest 28.75% from Indira Gandhi Canal. Due to transformation of open wells in pump wells ground water table varies 35-40m (1984-97), 45-50m (2010) as per central ground water board, 50-54m (2015) as per AMRUT report, 2015. Water supplied to city is mix of treated water Indira Gandhi Canal and Ground water after preliminary treatment, is not fit for potable uses as ground water level is contaminated with fluoride (1.5-3mg/l), nitrate (>100mg/l), salinity (>7000µS/cm) and high hardness as per Central Ground Water Board). Consumption of contaminated water leads to tooth problems (Fluorosis), weak bones (Arthritis), blue baby syndrome etc. Due to scarcity of alternate water source in city water extraction (9.9MLD) is more than permissible (7.1MLD as per ground water year book 2014-15, Rajasthan) to meet domestic water demand of City and pressure is also increasing on Indira Gandhi Canal as in it increase to 0.8MLD to 4MLD from 2010 to 2016 and it will increase to 12MLD for year more to satisfy future needs.

II. PRESENT SCENARIO OF RAINWATER IN CITY

Rain falling on the roofs of houses flows through outlet pipes and mix with polluted surface runoff and a large quantity of pure water from roofs gets wasted. As an alternate source for non-potable uses waste water is available but in present scenario due to open drains in city waste water is flowing to depressions and polluting rainwater too. Rainwater harvesting structures like Johad or ponds (Sethani Ka Johad), kunds which were common in Churu as source of fresh water are not well maintained and influenced by unwanted vegetation and now water available is not fit for potable uses. Main structure is available outside the city hence not influenced by waste water and solid waste disposal of city, no construction is taking place near it due to local authority attention but still a threat of encroachment is there. Churu has 632Ha of residential area in which 55% is dedicated to houses with 65% average built up, with collection efficiency of 70% as different roof materials are available. 632ML of water per year is available form roofs which can be collected to use as potable water, also water form surface with collection efficiency of 20% is available from various Landuse in city. 603ML of water is available to collect in community ponds in 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

Table 1: Surface runoff different landuse

Net surface runoff available for collection is 20% after considering different losses in infiltration, evaporation, transpiration etc. [1] So, rain is source of a fresh water in Churu City with 632ML of clean water and 603ML of water which is contaminated with ground impurities but can be used to maintain the city vegetation and landscaping. Therefore, it is required to collect the water so that exploitation of water sources can be checked by supporting them with an alternate source.

III. RAINWATER HARVESTING AND SUCCESSFUL STORIES

Rooftop Rainwater harvesting is the collection of purest form and primary source of water by using various techniques. The process of rooftop rainwater harvesting involves collection of rainfall from localized catchment surfaces such as roofs for direct use as potable water[2]. In Germany, a study performed showed that the potential of potable water saving in a house might vary from 30% to 60%, depending on the demand and roof area[3]. In Brazil, a study performed showed the potential water saving by using water harvesting in 62 cities ranges from 34% to 92%, with an average potential for potable saving of 69%[4]. In Jordan, The potential for potable water savings (200-600mm) was estimated for the 12 governorates, ranging from 0.27% to

19.7%. Gadarif city of Sudan could improve the drinking water scarcity applying rainwater harvesting system in semi-arid regions affected by climate change and population increase[5]. 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 [6]. It can be collected and controlled by the individual household or community as it is not open to abuse by other users. Rainwater harvetsing is a promising idea which can provide potable water at household and community level. It is mandatory for city to manage the source to check the exploitation for nnow and years to come.

IV. OBJECTIVE

The general objective of this research is to manage the potable and domestic water demand on various sources to check the exploitation of sources using Rooftop Rainwater Harvesting.

V. METHODOLOGY

This research is based on a simplified quantitative survey which consists a detailed questionnaire. This questionnaire contains a set of questions on various parameters like water consumption pattern, tank size, household size etc. Secondary sources has been referred to collect rainfall data, water supply status, ground water status etc. On the basis of detailed analysis, demand supply gap, potable water demand, management of sources has been carried out. Reconnainsance survey conducted in Churu city to know about status of rainwater harveting in holistic manner and detailed household survey of neighborhood with sample size of 50 houses.

VI. ANALYSIS OF DATA

A. *Rainfall analysis*

Rainfall data form year 1998-2016 is analyzed to get the average annual rainfall of City.

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Rainfall Mm	650	226	230	413	288	570	253	444	341	449	636	409	614	651	430	468	481	536	648

Source: Meteorological Department of India

Table 2: Annual Rainfall data of Churu city

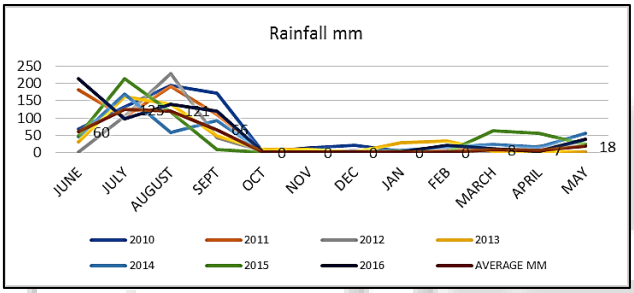

Fig. 1: Average rainfall data of Churu

Net average annual rainfall available for collection is 400mm in Churu city after considering the losses in first flush.

B. *Water consumption pattern*

Water consumption pattern of people decides the true water demand of an area, it is the basic requirement of research to understand the consumption pattern of Churu City which is based on their respective water meter bills and tank size available for the collection of water from municipal supply and their frequency of filling it, number of family members.

For plot size <100m²; Average meter charge: 43.62Rs which is after the deduction of water meter charge, service charge and maintenance charge imposed by department., Avg. household size: 5

Quantity	Charge/ 1KL
<8000L	1.56Rs
8000-15000L	2Rs
15000-40000L	4Rs
>40,000L	5Rs

Source: PHED Charge norms, 2015

Table 3: PHED water consumption charge

Average consumption(L) = 44.62*1000/4 =11,155L; LPCD: 11,155/(5*30)= 74.3L

Avg. storage tank= 750L, frequency=1.5-2days

LPCD: 750/(5*2): 75L

Plot size (m²)	Avg. Water bill Rs.	Avg. Household size	LPCD as per bill	Avg. tank (L)	LPCD
<100	43.62	5	74.3	750	75
100-225	55	6	91	1200	96
>225	73.5	5	117	1800	125

Table 4: LPCD based on Bill and Tank size

Area sqm	<100	100-225	>225
% Share	58	31	11
Average Demand (LPCD)	75	96	125
Weighted Average Demand (LPCD)			90

Table 5: Weighted average per capita demand

C. *Water sources & supply status*

Two water sources from which City gets water for domestic purposes Ground Water and Indira Gandhi Canal. As per data of Central Ground Water Board 2015, ground water available is 7.09MLD i.e. 47LPCD for 136500 population (2016). But extratcion of water is 10MLD out of which 8MLD for domestic uses i.e. 58LPCD.

	2016
PHED Total Supply	14MLD
GW	9916 KLPD (71.2%)
IGC	4000KLPD (28.8%)
Domestic Supply 80%	11.133 MLD
Average Per Capita Demand LPCD	90 LPCD
Transmission Losses	15%
Per Capita Water Supply	69 LPCD (76%)

Table 6: Water supply status of Churu City

Total water supplied to city is 11.13MLD i.e. 69LPCD against demand of 90LPCD sets gap of 23% in demand and supply with 100% shortage of potable water as water is supplied after mixing of two sources water. Water extraction from IGC is 4MLD, pressure is increasing as in 2010, demand is 5.5LPCD and in 2016 it is 22LPCD and it will increase to 63LPCD if it is not supported by any alternate source.

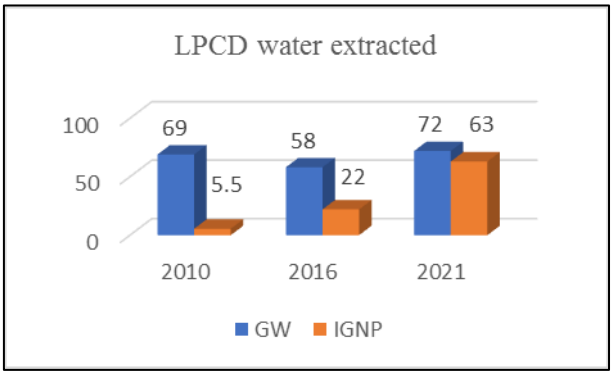

Fig. 1: Extraction of water: present and future

D. Population Projection

Population is projected on the basis of trends followed in previous which shows population will increase with 28% growth rate in coming years.

Year	Population	Growth rate
1971	53185	27.46
1981	62070	16.71
19991	82852	33.48
2001	101874	22.93
2011	120157	17.9
2016 proj	136500	23.2
2021Proj.	153680	28
2031Proj	197017	28

Table 7: Projected Population

E. Rainwater Potential of City

Quantity of rainwater= roof size X rainfall X runoff Coefficient (0.8)

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

Table 8: Rooftop Rainwater Harvesting Potential

Total rainwater available from the roofs is 530ML water per year.

VII. RESULTS AND DISCUSSION

A. Management of Sources

Rooftop Rainwater Harvesting has the potential to support potable water demand fully as discussed in potential of Rooftop Rainwater Harvesting in Churu. Potable Water demand of city is 498ML per year against 530ML per year rainwater. 10LPCD (11.1%) of total domestic demand is completed by Rainwater. Also, recycling of waste water form bathroom and kitchen can be done to supply 20LPCD (22.2%) for flushing of toilets.

OURCE	2016 Extraction from source LPCD	Available LPCD After RRWH	source LPCD	n Percenta
Ground Water	58	47	37	43.5	92%
IGC	29	29	23	29	-
Waste Water Recycle	0	-	20	23.5	-
Rainwater	0	-	10	10	-
Total	87	76	90	106	

Table 9: Management of sources

RRWH and recycling of waste water helps to mitigate the problem of exploitation of Ground water and at the same time source of potable water is available in city. Ground water extraction is decreased to 92% from 123%, net 31% of pressure decrease on ground water.

B. Tank capacity

Tank capacity should be based on the period of dry season, per capita demand, size of household. But in this case, dry period is of 8 months which needs a large capacity tank which is not feasible within setbacks available on plot size. Therefore, tank of 4KL for house <100sqm and 8KL for >100sqm is suggested. Water which is available in excess to limited quantity of tanks is supplied to community tanks which are located at neighborhood level and water can be extracted in dry season when individual tanks potable water finished.

			From Rooftop Area Of 75m² And Runoff Coefficient 0.80						

Months	Average	Demand@10 LPCD For 5 Members	RRWH Potential L	Table (2-1)	Storage Of Tank At The End Of Month	Tank Of 4KL	Community Tank L	Monyhly Water Contribution	Water To Community Tank LPCM	From Community Tank L	From C.Tank LPC	Dependency On Community Tank
		1	2	3	4	5	6	7	8	9	10	11
June	60	1500	2736	1236	1236	1236	0	0	0	0	0	
July	125	1550	5700	4150	5386	4000	1386	1386	277	0	0	
August	121	1550	5518	3968	9354	4000	5354	3968	794	0	0	
Sept	66	1500	3010	1510	10863	4000	6863	1510	302	0	0	
Oct	0	1550	0	-1550	9313	2450	0	0	0	0	0	
Nov	0	1500	0	-1500	7813	950	0	0	0	0	0	
Dec	0	1550	0	-1550	6263	-600	0	0	0	600	120	
Jan	0	1550	0	-1550	4713	-1550	0	0	0	1550	310	
Feb	0	1400	0	-1400	3313	-1400	0	0	0	1400	280	
March	8	1550	365	-1185	2128	-1185	0	0	0	1185	237	
April	7	1500	319	-1181	947	-1181	0	0	0	1181	236	
May	18	1550	821	-729	218	-729	0	0	0	729	146	
Total	405						6863	6863	1373	6645	1329	-44

Table 10: Individual tank potential to support potable water demand

Potable demand of 6 months can be taken care fully with 4KL tank in 5 members family. For the rest of the months people have to fetch wtaer drom community tanks.

Area SQM	Months
<50	6
50-100	6
100-162	6
162-225	6
225-350	7
>350	7

Table 1: Individual Tank capcity to satisfy potable demand

C. Projections of Rainwater for horizon year 2031

1) Housing and Houseless families status

On the basis of growth in Churu city, number of houses in 2031(1,97,017) projected and RRWH potential is analyzed.

Year	House	Numerical Increase	Family	Houseless		Growth Rate
1991	12652	-	14522	1870		-
2001	14437	1785	16979	2542		14
2010	17578	3141	20660	3082		22
2016	22460	4882	27300	4840		28
2021	24923	2463	30736	5813		11
2031	28180	3257	39403	11224		13

Table 12: Projected Houses and Houseless families

Houseless families act as rental families in city and increase the number of people per plot size. In year 2031, household size increase to 7 as housing unit increase at 13% rate whereas population with 28% growth rate

Projected rainwater quantity for year 2031 is calculated in following table:

Plot Size Sqm	<50	50-100	100-162	162-225	225-350	>350	TOTAL
Proportion	25	33	19	12	7	4	
Tank KL	4	4	8	8	8	8	
Demand LPCD	10	10	10	10	10	10	
House	7045	9299	5354	3382	1973	1127	28180
Rainwater Per Plot Per Year	10498	18468	30326	38880	46008	51597	
Water ML Per Year	74	172	162	131	91	58	688
Total Population Of City							197017
Total potable demand @10lpcd				197017X10X365			720ML

Table 2: Projected Rain water quantity for year 2031

For year 2031, waetr available is less than required, 95% demand can be met from rainwater therefore contribution form other landuse i.e. buildings with large roof area is required. Water from these roofs will be much more than required which can support demand more than 10LPCD which help in decrease pressure on other sources.

VIII. Recommendations

1) Recommendations in context to Churu city for neighborhood level planning:

- Plot size less than 100sqm (58%) extract water form community tank more than supplied and plot >100sqm (42%) supply more water than extraction. Therefore, community tanks are mandatory to construct so that excess water from large roofs can be used for people living in <100sqm plot.
- The siting of Community tanks should be based on site survey, topographical analysis preferably on open land available at Public buildings level, open spaces and parks/ playgrounds available in Churu city.
- All community tanks should be connected to each other and to the treated water of Indira Gandhi Canal which increase the per capita potable water to 33L which is 37% of per capita domestic demand (90LPCD) which is well above the potable demand for drinking and cooking.
- Levy differential charges for fresh potable water from community tank and also provide relaxation to those who are supplying water to community tanks in rainy season as per the quantity of water or extraction of same quantity as supplied by individual in rainy season is free.
- All expense required for construction of community tanks should be provided by Government and local authorities.

2) Recommendation in context to Churu city at city level are as follows:

- Waste water treatment plant in decentralized manner in the Churu city which can recycle water of 20LPCD to support domestic supply is required i.e. 136500X20= 2.73MLD (27%) is required from total waste water (136500X90X0.8) 9.82MLD.
- Waste water treatment plant at suitable location in city depending on the topographical survey of city, contour mapping is required preferably near to low lying area of city to treat waste water coming out from kitchen and bathrooms.
- Surface runoff rainwater is presently polluted by waste water through open drains in the city. Separate drains allow the sensible use of surface runoff rainwater available in low lying area of city.
- Waste water available after 2.73MLD supply to city can be used for landscaping in city

IX. Conclusion

An area with water sources under exploitation and water contaminated with fluoride, nitrate, chloride requires support from an alternate source to manage the increasing pressure on it. RRWH should be mandatory in such type of areas where sources are under pressure and health of public is at threat. RRWH can support the potable water demand for now and next 20 years if collected effectively. In such type of projects, community participation plays an important role along with Government Authorities. Projects of this nature should be implemented immediately for the welfare of the public and to provide source of fresh water at household level and community level. Design and location of community tanks is open to research which require deep analysis of area. Rooftop Rainwater Harvesting is an efficient tool as an alternate source of water supply for present and for the future in Churu City.

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