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Water Scarcity and Health Hazards in Changing Climate Scenario: A Case Study of a Semi-Arid Area in Rajasthan

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Abstract

Water is essential compound for life, having its prime usage in drinking and irrigation. The availability of water for consumption varies spatially due to various geographical and climatic factors. Areas which are mainly dependent upon ground water, the accessibility are also influenced by rainfall, which recharges it. Variation in rainfall due to climate change may affect the quality and quantity of ground water. Access to safe drinking water is essential for individuals as well as households for overall well being and development. The present study explores the water access scenario to the households in a semi-arid region of Rajasthan. Two distinct clusters having six villages each, has been formed on the basis of geo-ecological settings and 256 rural households have been randomly selected for primary study. The impact of climate change on water availability has been studied through trend analysis of rainfall and temperature at one meteorological station in each region. The source and access distance of drinking water has been analyzed on the basis of responses given by the households. The health related hazards being perceived by the households due to the quality of drinking water have also been studied. Both quantitative and qualitative techniques have been used to assess the situation at ground level and suggestions have been given for improving the quality as well as accessibility to water for larger policy implications.

Keywords: Water, Climate Change, Potable, Semi-Arid Region, Health Hazards.

Introduction

Water is essential compound for life and can be considered as precious gift of nature. However the availability of the water varies spatially and is influenced by various geographical and climatic factors. The availability of the water in arid and semi-arid areas suffers from negative stresses as the surface water resources are less in number. The fourth assessment report of IPCC in 2007 predicted that there will be a decrease in water resources in semi-arid and arid areas due to impacts of climate change (IPCC, 2007). Similar observation has been given in the IPCC's fifth assessment report that the climate change may reduce the availability of surface and ground water resources especially in dry and sub-tropical regions (Jiménez Cisneros, B.E., T. Oki, N.W. Arnell, G. Benito, J.G. Cogley, P. Döll, T. Jiang, 2014).

The state of Rajasthan faces water deficit as 75% of its geographical area falls under arid and semi-arid regions. Besides, the water being a scarce resource in the state, the distribution of water resources is also not even. The per capita availability of water is less than 1000 meter^3 per year (*Rajasthan State Action Plan on Climate Change*, 2014). The report "Women and Water" published by National Women Commission, 2005 observed that in Rajasthan women and girl children mainly have to owe the responsibility for water collection, thus spending most of their productive time in collection of water. The report further observed that a woman has to travel on an average about 14000 km in a year for collection of water (National Commission for Women, 2005). The state of Rajasthan is having more than 50% of the total villages affected by fluoride in India (Singh, Rani, Singh, & Maheshwari, 2011). Hussain *et al.,* (2004) observed that almost all the districts of Rajasthan were affected by high fluoride content in drinking water and the researchers classified the district Sikar into a 'serious' category wherein 25% – 50% villages were having fluoride content in excess to the permissible limit (Hussain, J., Sharma, K. C. Hussain, 2004, pp. 265).

Aim of the Study

The present study has the following objectives:

1. To find out the impact of Climate change on water availability scenario for households in a semi-arid region of Rajasthan.
2. To examine the level of scarcity which the households of two distinct geo-ecological areas face in accessing drinking water
3. To find out the health hazards, the households face due to quality of drinking water.

Review of Literature

Semi-arid areas are "transitional zone between arid and sub-humid belts, where precipitation is less than potential evaporation" (Huang *et al.,* 2010, p. 6863).In the state of Rajasthan, the availability of surface water is insufficient thus there exists large dependency upon the ground water resources. Recurring droughts, large sandy tracts and disorganized drainage pattern exert an additional pressure upon ground water resources (*Rajasthan State Action Plan on Climate Change*, 2014). The India's second national communication also observed that higher amount of extraction of ground water with the lesser replenishment will lead to depletion of water table thus affecting the quality of ground water. The report further stated that precipitation which is the main source of recharging the aquifers is erratic in semi-arid and arid areas. Rainfall occurs in splashes for short durations leading to fast run-off rather than charging of ground water resources (NATCOM, GOI, 2012).

The proposed district of study falls under semi-arid area (Gore P.G, Roy, B. A, Hatwar, 2011).The ground water resources of the Sikar district has been assessed by Central ground water board and State Government water board, and on the basis of the net availability of ground water in the district, all blocks have been declared as "over exploited" except for Fatehpur (Central Ground Water Board, 2013). Abhay, 2013 extensively studied the water availability situation in Sikar district and found that ground water which was a major source is 'over exploited' in the district (Abhay, 2013). In another study conducted by Yadav and Yadav, concluded that the availability of ground water in the district is 'grim' (Yadav and Yadav, 2014).

The ground water has higher fluoride content than running surface water. This may happen due to the dissolution of fluoride minerals during the percolation of water through the rocks (Arif M, Husain I, Hussain J, 2013). Many studies have found that the state of Rajasthan is highly affected by fluoride (Ayoob & Gupta, 2006; Hussain *et al.,* 2010; Sharma *et al.,* 2007; Singh *et al.*, 2007). As per the WHO norms, the permissible limit of fluoride is 1.5 mg/ liter (Barmes, 1994) whereas the Bureau of Indian Standards suggested the permissible limit as 1.5 mg/ liter when there are no alternate available sources (BIS, 2012). The level of fluoride more than permissible thresholds may cause fluorosis and other musclo-skeletal disorders (Arif *et al.,* 2013; Hussain *et al.,* 2003; 2004; 2012; Singh & Garg, 2012; Suthar et al., 2008).Saxena and Saxena in 2014 evaluated the quality of water at Bassi tehsil, Jaipur and found fluoride and nitrate levels were more than the permissible limits (Saxena and Saxena, 2014).

There have been studies which have analyzed the ground water quality of district Sikar by various methods and found high fluoride contents (Rawat & Jakher, 2007; Shyam & Kalwania, 2012). The ground water atlas prepared by Rajasthan ground water board has shown that the 31% part of the district has a higher content of fluoride concentration (1.5-3.0 mg/ liter) which lies more in western and central part of the district. The areas in the north of the district have a concentration even more than 3.0 mg/ liter which constitutes 6% of the district (*Hydrogeological Atlas Of Rajasthan: Sikar District*, 2013). Meenakshi and Maheshwari reviewed various methods available for treatment of water with high fluoride content on the basis of literature and laboratory outcomes. The researchers have suggested that the method employed should suit the specific requirement of the location where treatment has to be done (Meenakshi & Maheshwari, 2006).

Area & Method of Study

The present study has been carried out in Sikar district, located in the north-eastern part of the Rajasthan with longitude 74.44˚E to 75.25˚E and latitude 27.21˚N to 28.12˚N (Census of India-2011, 2011). The district has no perennial river but there are few streams called 'Mendha', 'Kantli', 'Dohan', 'Krishnawati' and 'Sabi'. There are no big lakes in the district except for a lake at Peethampuri in Neem Ka Thana which has no significant contribution in irrigation (B. D. Agrawal, 1978, p.6).

Sampling

Twelve villages from nine *tehsils* of the Sikar district have been selected through purposive sampling method for clustering the villages on the basis of geo-ecological characters. Two clusters have been formed for comparative study and they have been called as fragile ecological cluster and non-fragile ecological cluster. A total of 256 rural households have been sampled from 12 villages using simple random technique. 2% households were sampled from villages having more than1000 households, 3% from villages having more than 500 households whereas 5% houses were sampled from the villages having less than 500 households. The fragile cluster included three hilly villages namely Raiwasa, Harsh and Dareeba and three sandy villages Dhandhan, Magloona and Udansari with 114 sampled households. In non-fragile cluster the villages were non-sandy and non-hilly namely Piprali, Dhalyavas, Kasli, Mau, Nangal and Mandoli with 142 sampled households.

Data Collection

A questionnaire was canvassed for collecting data on accessibility of drinking water and the health issues of the households due to quality of drinking water. The secondary data of temperature for period

1973 – 2009 has been procured from India Meteorological Department (IMD), Pune whereas the rainfall data for period 1957 – 2013 has been procured from Rajasthan government water resource website (Water.rajasthan.gov.in, n.d.).

Analysis of Data

The rainfall and temperature trends have been calculated using the Man Kendall test and Sen's slope estimator. The descriptive statistics like mean, standard deviation, coefficient of variation and slope have been calculated for secondary climatic data for two stations i.e. Lachhmangarh in fragile ecological cluster and Sikar in non-fragile ecological cluster

The Mann-Kendall test has been employed for ascertaining the presence of monotonic trend in rainfall time series data. It is simple, rank based and robust test in its output and has an added advantage for accommodating missing values in the data (Kundzewicz & Robson, 2004). It has been used to detect trend in rainfall and temperature data by various authors (Basistha, Arya, & Goel, 2009; Pingale, Khare, Jat, & Adamowski, 2014; Patra, Mishra, Singh, & Raghuwanshi, 2012; Rathore, Attri, & Jaswal, 2013). The statistics for the series R_1, R_2…..R_n can be explained as follows

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(R_i - R_j)$$

$$\operatorname{sgn}(R_i - R_j) = \begin{cases} 1 & \ldots \quad if\ R_i > R_j \\ 0 & \ldots \quad if\ R_i = R_j \\ 1 & \ldots \quad if\ R_i < R_j \end{cases}$$

The Theil-Sen's Slope estimator or Sen's Slope is a non parametric, linear slope estimator used for quantifying the trend, when the Mann-Kendall test identifies either positive or negative trend in the time series data. The positive value of the slope depicts an increasing or 'upward trend' whereas negative value is a sign of decreasing or 'downward trend' (Karpouzos, Kavalieratou, & Babajimopoulos, 2010; Chakraborty, Pandey, Chaube, & Mishra, 2013). The rainfall and temperature trends have been calculated using the Man Kendall test and Sen's slope estimator. The descriptive statistics like mean, standard deviation, coefficient of variation and slope have been calculated for secondary climatic data for two stations i.e. Lachhmangarh in fragile ecological cluster and Sikar in non-fragile ecological cluster.

The responses collected from the households have been presented in form of frequencies calculated as percentage. The observations and responses during the focus group discussions and personal interview have also been presented along with the quantitative analysis.

Results & Analysis

The rainfall pattern for the station Lachhmangarh in fragile eco-cluster and station Sikar in non-fragile eco-cluster have been analyzed for four monsoon months. Descriptive statistics like mean, standard deviation and coefficient of variation along with the slope, Man Kendall value and Sen's slope has been presented in Table 1. It can be clearly observed that there is a significant declining trend of rainfall at Lachhmangarh station in the month of July which is considered as significant month for rainfall in southwest monsoon season. The rainfall has been decreasing at the rate of -2.15 mm/ hydrological year.

Table 1: Analysis of Rainfall Pattern for Monsoon Months

Months	**Rainfall (mm)**						
Period (1957-2013)	Mean	SD	CV (%)	Slope	MK	p-Value	Sen's Slope
			Lachhmangarh				
June	59.32	55.24	93.13	1.03	0.159	0.158	0.587
July	157.95	120.18	76.09	-2.69	-0.258	**0.005*** **	-2.151
August	117.72	108.91	92.51	0.65	0.077	0.464	0.632
September	48.72	51.06	104.82	-0.22	0.020	0.733	0.000
Monsoon season	383.70	183.67	47.87	-1.23	-0.085	0.260	-1.136
			Sikar				
June	59.26	75.78	127.88	0.98	0.226	**0.000*** **	0.716
July	178.48	132.48	74.23	-2.56	-0.229	**0.012** **	-2.106
August	140.71	124.95	88.80	1.11	0.080	0.285	0.667
September	54.38	56.23	103.41	0.38	0.020	0.846	0.067
Monsoon season	432.82	205.70	47.52	-0.09	-0.020	0.854	-0.367

Note: *, **, *** indicates Significance at 10%, 5% and 1% respectively. (Based on own calculations)

The Man Kendall test has also detected a decrease in the seasonal monsoon rainfall for the Lachhmangarh station; however it was the statistically significant. Similarly it can be observed from the table for Sikar station located in non-fragile ecological cluster, that there is a significant declining trend of rainfall for the month of July. The decline is at the rate of -2.106 mm/hydrological year. The mean monsoon seasonal rainfall also depicts a declining trend at Sikar station however it is not significant. The above analysis of long term average at the two stations in fragile as well as non-fragile ecological cluster indicates that the rainfall has been decreasing. Since the rainfall is an important source for recharge of the ground water, the declining trend of the rainfall especially during the monsoon months definitely will have an adverse affect on the recharge of the ground water resources which is the main source of water in the study area.

The maximum temperature for the monsoon months have also been analyzed for observatory stations Fatehpur and Sikar located in the fragile and non-fragile clusters. The Man Kendall test detected a significant increasing trend of maximum temperature at Fatehpur for the month of August and September.

Table 2: Analysis of Maximum Temperature For Monsoon Months

Months	Maximum Temperature (˚C)						
Period (1957-2013)	Mean	SD	CV (%)	Slope	MK	p-Value	Sen's Slope
				Fatehpur			
June	38.82	1.75	4.51	0.00	0.027	0.816	0.003
July	33.85	1.73	5.10	0.02	0.032	0.780	0.007
August	32.68	1.04	3.19	0.04	0.305	**0.001*** **	0.030
September	32.78	1.31	4.00	0.04	0.320	**0.004*** **	0.051
Monsoon months	34.53	0.97	2.81	0.02	0.167	0.133	0.016
				Sikar			
June	39.87	1.89	4.74	0.04	0.130	0.266	0.035
July	34.77	2.24	6.43	0.00	-0.060	0.610	-0.013
August	33.65	1.65	4.92	0.01	0.063	0.592	0.012
September	34.11	1.84	5.38	0.02	0.075	0.521	0.015
Monsoon months	35.60	1.51	4.25	0.02	0.045	0.707	0.007

Note: *, **, *** indicates Significance at 10%, 5% and 1% respectively. (Based on own calculations)

From the table it can be observed that most of the months in both the stations are showing increasing trend of maximum temperature. Increase in temperature will be one of the important contributing factors for increasing the evapotranspiration in the monsoon months which are the main cropping period in the study area. Increase in evapotranspiration will require more irrigation for sustaining the crops which in turn may put additional stress on ground water resources. Thus increase in maximum temperature and decrease in rainfall can be detrimental for the ground water resources in the district, where the situation is already reported to be adverse by various studies.

The various source of drinking water of the households have been represented in percentage in Table 3. The households located in fragile ecological cluster have a better access of tap water (66.70%) than the non-fragile ecological cluster households (60.60%). The reasons may be due to larger interventions of public agencies in providing tap water for the rural communities.

Table 3: Source of Drinking Water as Reported By Households (in %)

Source of Drinking water	Tap	Hand pump	Tube well	*Bawri* (Pond)
Fragile Eco Cluster (*n*=114)	66.70	23.70	5.30	4.40
Non Fragile Cluster (*n*=142)	60.60	19.00	20.40	0.00

(Based on primary survey)

The use of hand pumps is more in fragile ecological cluster (23.70%) than non-fragile ecological cluster (19%) and this may be again more in former case due to community hand pumps which have been installed by public agencies at common places. The source for the water as tube well is less in fragile ecological system (5.30%) than non-fragile ecological system (20.40%) as tube wells in fragile villages are either difficult to dig or it is salty and not fit for drinking as in case of Magloona and Udansari villages in Lachhmangarh and Fatehpur tehsil. About 4.40% households in fragile ecological cluster have reported for using traditional *bawris* for drinking water.

The distance travelled by the household members for collecting drinking water has also been analyzed and it can be seen from the Table 4 that 65.80% households in fragile ecological cluster have access to drinking water either in their house premises or near to it whereas the percentage is far behind in non-fragile ecological cluster. The reason may be again due to interventional policies of better water supply in areas where the drinking water is a scarce commodity.

Table 4: Distance Travelled for Accessing Drinking Water (in %)

Distance travelled	Within premises (0 km)	Up to 0.5 km	1 km or above
Fragile Eco Cluster (*n*=114)	65.80	28.90	5.30
Non Fragile Cluster (*n*=142)	57.00	38.70	4.20

(Based on primary survey)

The percentage of households, who have to travel a distance upto 0.5 km in non-fragile ecological cluster, is again high (38.70%) than fragile ecological cluster (28.90%), whereas it has a marginal difference for distance more than 1 km. The above facts indicate that the scarcity of the drinking water is increasing even in the non-fragile ecological cluster which is lesser fragile than the earlier category.

The households of the both clusters were quite aware about the high fluoride content present in the drinking water. During focus group discussions, one of the respondents at Dhandhan village lamented "*Half of the village population will become lame due to drinking water. Instances of skeletal disorders are very high in the village.*" In village Raiwasa during interview with the gram sabha functionary, he told "*Younger generation will face more problems due to high fluoride contents and if the situation continues in near future, people will have serious skeletal and gastro problems while they reach age of 25 years.*" The households reporting the diseases that they perceived due to the quality of the drinking water is being presented in Table 5.

Table 5: Disease Reported By The Households (in %)

Disease reported	Non such diseases reported/ unaware	Gout/ Skeletal fluorosis	Stone in gall bladder/ gastro-intestinal disorders	Dental Fluorosis	Any other
Fragile Eco Cluster (*n*=114)	13.20	53.40	24.60	8.80	0.00
Non Fragile Cluster (*n*=142)	28.20	40.80	21.10	8.50	1.40

(*Based* on primary survey)

The instances of gout and muscular-skeletal disorder were high in fragile ecological cluster (53.40%) than the non-fragile ecological cluster (40.80%). The villages included in the fragile cluster were mainly in Fatehpur, Lachhmangarh, Ramgarh Shekhawati, Neem Ka Thana and Danta Ramgarh tehsils which have reported high contents of fluoride. The Hydrogeological Atlas for groundwater of Sikar District, reported the percentage of area at block level that has fluoride content between 1.5-3.0 mg/litre as Fatehpur having 58.1% out of its total area, Lachhmangarh having 48.6%,Dantaramgarh having 14.3% whereas in Neem ka Thana block, 13.1% area was having high range. The range more than 3.0mg/litre was maximum in Fatehpur (22.2%) followed by Dantaramgarh (7.5%) and Lachhmangarh (5.1%).The blocks which falls under non-fragile cluster even have higher areas in range of 1.5-3.0 mg/litre as Khandela having 47.5% and Dhond is having 20% of its area with a higher level of fluoride in groundwater (*Hydrogeological Atlas Of Rajasthan: Sikar District*, 2013, pp.15).

The cases reported regarding gastro-intestinal disorders have been high in fragile ecological cluster (24.60%) than the non-fragile ecological cluster (21.10%). The reporting for dental fluorosis has been almost similar in both the clusters with marginally more in fragile ecological cluster. However the fluoride is considered to be an essential micro element but when it enters in human body above the threshold limit it causes toxicity leading to dental and skeletal fluorosis (Arif *et al.,* 2013). The study carried out by State Institute of Health and Family welfare , Jaipur has regarded the district Sikar as one of the worst fluoride affected district (SIHFW, 2008), which supports the observed high level of disease reporting by the households in both the clusters.

Suggestions

The current situation can be improved by the following suggestions which can be implemented at three tier level.

At Individual Level

Since 33.4% in fragile cluster and 39.4% in non-fragile cluster consumed directly ground water through hand pump, tube well and bawri, which may be having high fluoride contents as reported in many studies. The households should explore the alternative source, i.e. rain water which is the purest form of the water. For rain water harvesting and its utilization, technical training and financial aid is required.

At Community Level

The percentage of households who have to travel for accessing water is high in both fragile (34.2%) and non-fragile (42.9%). Community supply of water can be done through making water harvesting structures. The installation and maintenance of de-fluoridation plants or technology can be initiated at village or *dhani* level with participation of the community for supply of potable water to the households.

At Government Level

The health issues reported by the households is quite high in both the clusters as 86.8% households in fragile and 71.8% in non-fragile cluster have reported health issues being suffered by the households members due to quality of drinking water. At government level, the number of rain water harvesting structures may be increased in consonance with the population of the affected areas. Primary technical survey can be carried out at village level for estimation of the water quality. On the basis of local requirement installation of de-fluoridation plants can be done, for at least between 2 – 3 *gram panchayats* after assessment of the local requirement.

Conclusions

From the above study it can be concluded that the rural households have to face scarcity of the water in the semi-arid district Sikar, Rajasthan. Though the water is supplied through taps in many of the households but still it is high in fluoride content as perceived by the households. Besides scarcity, the quality of water is a major health hazards especially in sandy and hilly villages. However the reporting from other cluster of non-sandy and non-hilly is also very high and cannot be ignored. The analysis of long term pattern of rainfall depicted a declining trend in the precipitation whereas the maximum temperature shows an increasing trend and combination of these two trends in the climatic parameters will affects the quantity as well as quality of the ground water.

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