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Drinking Water Suitability and Management of Jayal block of Nagaur District, Rajasthan, India

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ABSTRACT
Water is source of living world. We can live without food for long time but without water not more than week time Jayal block falls in the district of Nagaur district has not only scarcity of water resources but also adversely affected quality of precious groundwater assets. In view of acute water crisis, water resources studies (especially hydro-geochemical investigations causing health hazards) were carried out in Jayal block of Nagaur district for identifying various water related issues and to explore management options thereof. A total of 20 wells were identified as monitoring stations and water samples were collected and analysed for pH, electrical conductivity, total dissolved solids (TDS), fluoride (F),chlorides (Cl^-), and nitrates (NO_3^-). Fluoride concentrations in surface and groundwater collected from these villages varied between 0.0 and 5.7.0 mg/l. Groundwater contained high concentrations of fluoride in deep wells as compared to shallow dug wells and pond water, which could be due to occurrence of fluoride bearing minerals in various geo-formations in the area. Dental and skeletal fluorosis and deformation of bones in children as well as adults were observed in the study area owing mainly to excess fluoride concentration in drinking water. The area also witnesses high TDS in sub-surface water. Fluoride concentrations showed good correlation with TDS & EC compared to other chemical parameters like nitrate, and chloride constituents. The major issues in the block area include less availability of surface water due to low rainfall, high potential evapo-transpiration, occurrence of frequents droughts, deep and declining groundwater levels.
***Keywords**: Chemical parameters, Physical parameter, Jayal, groundwater.*

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INTRODUCTION

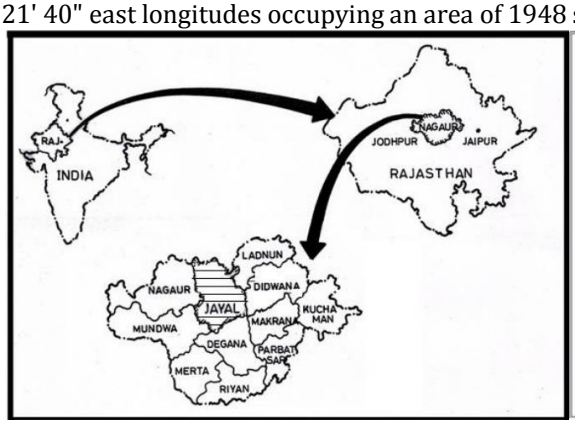
Water is essential for every living organism including human beings. Owing to enhanced aridity in western Rajasthan, there is acute crisis of availability of freshwater. Groundwater in Jayal block of Nagaur district is deep and rapidly declining due to its over-exploitation and its quality is also poor affecting human health in major parts of the district. Rainfall is low and groundwater resources are rapidly depleting in the study area. Nagaur district is known for Banka Patti (Banded skeleton) because of high fluoride concentration in drinking water. Therefore, groundwater studies (especially quality aspects) were undertaken in Jayal block of Nagaur district and for addressing various water related issues. Rainfall in the area is scanty and scattered along with high potential evapo-transpiration resulting in reduced availability of surface water and less natural groundwater recharge. The area is prone to frequent spells of chronic drought situations. Among the water quality parameters, fluoride ion exhibits unique properties as concentration in optimum dose in drinking water is advantageous to health and if the concentration exceeds the certain limit, this adversely affects the human health. According to WHO, suitable limit for fluoride in drinking water are 1.0 mg/l .Nineteen states in India have been identified as endemic for fluorosis and Rajasthan state is one of them. In Rajasthan state alone, most of the districts are affected by fluorosis. Nagaur district is the worst affected by fluorosis in the Rajasthan state. Though fluoride enters the human body mainly through drinking water (75%), food, industrial exposure, drugs, cosmetics, etc., are also sources of fluoride. Excess Fluoride affects plants and animals also. The effect on agriculture is also evident due to inhibition on plant metabolism leading to necrosis, needle scratch and tip burn diseases. In animals also prominent symptoms of fluorosis were distinguish. De-fluoridation/desalination using non-conventional energy, regulatory measures etc [11]. In human beings,

effects on dental and skeletal tissues (genu valgum) can occur in adolescents and young adults and even in children under 10 years of age among communities exposed to high levels of fluoride. Fluoride is primarily excreted through urine. The severity of injury is determined by duration of fluoride exposure and its concentration[8].

MATERIAL AND METHODS

STUDY AREA

In the central of the state of Rajasthan, Nagaur district is situated almost and extends between North latitudes 26°25' and 27°40" and East longitudes 73°10" and 75°15".There are 13 tehsil headquarters in the district viz. one of them is Jayal, The district is divided into 11 blocks (Panchayat Samitis) viz. Nagaur, Mundwa, Jayal, Merta,Makarana Riyan, Didwana, Ladnun,Degana, Parbatsar, and Kuchaman. A map showing the blocks of the district is presented in Figure – 1.Located in northern part of the Nagaur district, the Jayal block lies between 26° 56' 29.1" and 27° 32' 34" North latitudes and 73° 49' 44.5" and 74° 21' 40" east longitudes occupying an area of 1948 sq.km.[7]



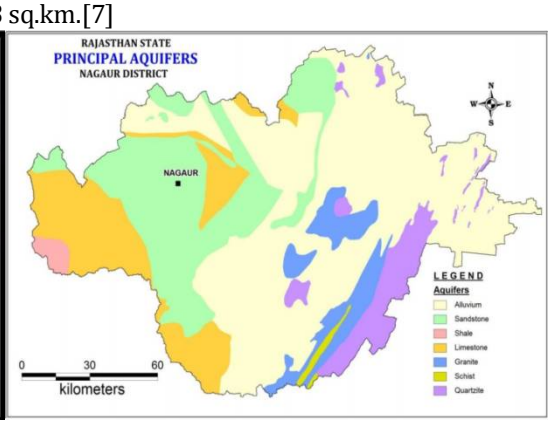


Figure: 1. Political Map of Jayal Block in Nagaur Figure: 2. Aquifer condition of Nagaur district, district Rajasthan.district, Rajasthan.

Nagaur district

Hydro-geologically, the whole Nagaur district area can be classified into three major formations viz. 1. Consolidated formations, 2.Semi-consolidated formations,3.Unconsolidated formations. Consolidated formations comprise of metamorphic rocks like phyllitesschists, gneisses, and quartzites of Precambrian age and sandstone and limestone of Marwar Super group. Semi-consolidated Formation sinclude Palana Sandstone consisting of very coarse grained, gravelly with intercalations of clay with kankar and lignite. Quaternary alluvium is the potential aquifer which is comprised of unconsolidated to loosely consolidated fine to coarse grained sand having interrelationship and intermixing with silt, clay with `kankar. [14], [1], [2]

Jayal block

Geomorphic landscapes in the Jayal block mainly include sandy alluvial plains, buried pediplains and pediments. Normal rainfall (1901-1970) in the block is 363.1 mm. Sandstone of Nagaur Group and Tertiary age constitutes aquifer systems in major parts of the Jayal block. Bilara Limestone and unconsolidated Quaternary formations also forms aquifer systems. Depth to water level in the block area varies from 36.70m at Mundi to 89.50m at village Khatoo-Kalan during pre-monsoon, (RGWD report 2019). As per groundwater estimates 2013 (published in 2017), potential freshwater recharge zone in the Jayal block is about 1744sq.km. Total recharge in the potential zone in the block is 58.4688mcm while total groundwater extraction for all purposes (domestic, industrial and irrigation) is of the tune of 54.6875 mcm. Stage of groundwater development is 103.93% and there for the block is categorized as Over exploited. The study area in Jayal block, Nagaur district is also known for Lignite deposits of Bikaner–Nagaur basin, The sandstone, shale, claystone and lignite sequence repeats at regular intervals.

Water level fluctuation: Pre-monsoon groundwater level in monitoring stations of Jayal Block reveals depletion in all wells from the year 2009 to 2018. The fluctuation level of year 2009 in post-monsoon indicates that there is depletion in ground level in four well whereas in the year 2018 two wells get dried up and there was depletion in other two wells. In village Khatu-kallan in the year 2009 there was depletion of three meters whereas in year 2018 there was rise of two meters.

Table 1. Groundwater fluctuation in year 2009 Jayal block of Nagaur District [12].

S.No.	Block	Rock formation	Rainfall in (mm)	Pre-monsoon (Water level from Ground Surface in meter)	Post-monsoon(Water level from Ground Surface in meter)	Water level Fluctuation in meter
1.	Jayal	Sandstone	228.0	38	37	+1
2.	Jhareli	Sandstone		40	41	-1
3.	Khatu-Kallan	Sandstone		108	111	-3
4.	Mundi	Tertiary Sandstone		34	35	-1
5.	Tarnau	Older alluvium		45	46	-1
6.	Bodwa	Bilara Limestone		52.39	52.45	-0.06
7.	Arwar	Tertiary Sandstone		28.00	27.80	0.2
8.	Deu	Sandstone		51.38	52.18	0.8
9.	Barnel	Bilara Limestone		59.04	58.20	0.84
10.	Chajoli	Sandstone		72.00	72.45	-0.45
11.	Kalvi	Older alluvium		40.50	40.80	-0.30
12.	Roll	Bilara Limestone		16.20	15.70	0.5
13.	Boseri	Sandstone		43.80	44.32	-0.34
14.	Jhun-Jala	Tertiary Sandstone		36.59	36.93	0.10
15.	Khanwar	Bilara Limestone		50.10	52.00	-1.9
16.	Dugoli	Older alluvium		41.55	41.35	0.20
17.	Pindia	Sandstone		108.97	111.2	-2.05
18.	Khabriana	Older alluvium		97.72	73.10	-0.13
19.	Surpaliya	Older alluvium		38.76	34.76	4.00
20.	Soneli	Bilara Limestone		16.20	15.70	0.5

Table 2.Groundwater fluctuation in year 2018 Jayal block of Nagaur District [13].

S.No.	Block	Rock formation	Rainfall in (mm)	Pre-monsoon (Water level from Ground Surface in meter)	Post-monsoon (Water level from Ground Surface in meter)	Water level Fluctuation in meter
1.	Jayal	Sandstone	00.00	Dry	Dry	-
2.	Jhareli	Sandstone		Dry	Dry	-
3.	Khatu-Kallan	Sandstone	293.0	109	107	+2
4.	Mundi	Tertiary Sandstone		36	38	-2
5.	Tarnau	Older alluvium		57	58	-1
6.	Bodwa	Bilara Limestone		56.50	56.10	0.40
7.	Arwar	Tertiary Sandstone		47.18	47.53	-0.35
8.	Deu	Sandstone		36.42	36.43	-0.01
9.	Barnel	Bilara Limestone		10.75	10.08	0.67

10.	Chajoli	Sandstone		47.18	47.53	-0.35
11.	Kalvi	Older alluvium		56.50	56.10	0.40
12.	Roll	Bilara Limestone		28.20	27.54	0.46
13.	Boseri	Sandstone		12.50	12.05	0.45
14.	Jhun-Jala	Tertiary Sandstone		32.60	31.76	0.84
15.	Khanwar	Bilara Limestone		55.53	56.45	-0.92
16.	Dugoli	Older alluvium		48.70	48.65	0.05
17.	Pindia	Sandstone		45.50	45.57	-0.07
18.	Khabriana	Older alluvium		30.50	30.50	0.0
19.	Surpaliya	Older alluvium		60.35	61.15	-0.8
20.	Soneli	Bilara Limestone		31.85	31.27	0.58

GROUNDWATER QUALITY:

To assess the suitability of groundwater for domestic use, Indian Standards of Drinking Water (IS. 10500. 2012) has prescribed standards for various chemical parameters for drinking water as follows.[5]

Table 3.Indian Standards of Drinking Water (IS. 10500. 2012)

S. No.	Parameter	Acceptable limit	Max. Permissible limit
1.	EC	1500µS /cm	2000µS /cm
2.	TDS	500mg/l	1500mg/l
3.	pH	6.5-8.5	No relaxation
4.	Cl^{-1}	250mg/l	1000mg/l
5.	NO_3^{-1}	45(mg/l)	No relaxation
6.	F^{-1}	1.0 mg/l	1.5mg/l

A total of twenty groundwater samples were collected for chemical analysis from observation wells from 20 villages located in Jayal block of Nagaur district. The groundwater samples were collected from bore wells, hand pumps and also from dug wells. Samples were collected in clean and sterile one-liter polythene cans and stored in an icebox (GWD.2009,2018). Analysis of groundwater samples collected from these villages has been carried out by Rajasthan Ground Water Department. The analysis for chemical parameters including fluoride in groundwater was carried out according to the procedure outlined in standard methods [3]Analysis was carried out for pH, electrical conductivity (EC), total dissolved solids (TDS), chlorides (Cl^-), nitrates (NO_3^-) and fluorides (F^-) and for other parameters. [7], [4]Fluoride ($F^{-)}$ was determined by SPANDS reagent method using colorimetric [6]

RESULTS AND DISCUSSION

All the groundwater samples collected in the study area were clear without any visible color, odor and turbidity. Impact of Fluoride concentration in drinking water on human health in a region also depends on its climatic conditions. The amount of water consumed and consequently the amount of fluoride ingested is being influenced primarily by the air temperature and other such climatic conditions. Owing to hot arid climatic conditions, intake of drinking water (containing high fluoride)is much more as compared to other regions and therefore seriously affecting human health in the study area and therefore emphasized in this appear. The results indicated that deep bore groundwater have higher concentration of fluoride compared to shallower open wells and pond water. This may be due to the fact that the major source of fluoride in groundwater is because of the deeper litho-formations in the area[10].The rock types including granites and gneisses containing fluorite and fluoropatite in this area attributes presence of high fluoride concentration in groundwater. From the data, it is evident that the study area is dominance by severe fluorosis. During reconnaissance survey of the study area, the people were found suffering from fluorosis. Skeletal deformation, weakening of joints and teeth mottling were observed in inhabitants of

the study area, which may be attributed to the presence of high levels of fluoride concentration in drinking water[15]Fluoride concentration in the study area is depicted in Figure 2. Fluoride concentrations in the study area varied from 0.0 mg/l to 5.7mg/l 10% well are suitable for drinking purpose year 2009.during pre-monsoon period. Fluoride concentration shows variation from 0.0 mg/l to 5.7mg/l. 20% well are suitable for drinking purpose during post-monsoon 2018. Overall concentration of Fluoride is high in most of the villages, but it is within permissible limit in some of the villages in the block e.g. Khatu-Kallan in the year 2018.Most of the samples analysed showed pH values between 7. 8 and 8.8 against the prescribed permissible limit for drinking water i.e. 6.5-8.5 of Indian Standards. Maximum pH was observed (8.8)(8.6) in Barnel and Boseri99% well suitable for drinking purpose villages in the year 2018. The trend of pH variations in groundwater and surface water samples analysed is depicted in figure maximum value of electrical conductivity was found at Tarnau (16,300mS/cm)10% well suitable for drinking purpose pre-post monsoon year 2009and 2018 and 5% well suitable for drinking purpose pre-post monsoon in the year 2009and 2018 while the minimum electrical conductivity value was found Tarnau (600mS/cm) in year 2018.The prescribed permissible limit of TDS for drinking water is 500 mg/l. TDS concentrations above 500 mg/L was noticed in most of the villages in Jayal block of Nagaur district. Highest TDS was observed at Jhareli village (9565mg/l) in the year 2018 while minimum TDS concentration was found at Tarnau (329 mg/l). Higher concentrations of TDS observed in groundwater of the study area may be mainly attributed to the aridity coupled with lithology in the study area.10% well suitable for drinking porpose pre-post monsoon 2009and 2018. The 100% well suitable for drinking purpose nitrate point of view average value of nitrates was found to be less than 5 mg/l, which slightly exceeded the prescribed permissible limits. The chloride value 100% suitable for drinking. The data obtained after analysis of all the water samples were compiled parameter wise and presented in Figure3 to 16 and tabulated in Table 1 to 9.

Table 4. Pre and Post-monsoon fluoride concentration in Jayal Block, Nagaur district in the year 2009.

S.No.	Well Location	Rock formation	Pre-monsoon (F^{-1} mg/l)			Post-Monsoon (F^{-1} mg/l)		
			Year (2009)	Year (2018)	Variation (2009-2018)	Year (2009)	Year (2018)	Variation (2009-2018)
1.	Jayal	Sandstone	3.04	5.2	+ 2.16	0.70	5.2	+4.50
2.	Jhareli	Sandstone	1.84	3.08	+ 1.24	1.00	3.08	+2.08
3.	Khatu-Kallan	Sandstone	3.74	0.60	- 3.14	3.20	0.60	-2.60
4	Mundi	Tertiary Sandstone	2.96	3.20	+2.24	2.60	3.20	+0.60
5.	Tarnau	Older alluvium	3.46	1.20	- 2.26	0.50	1.20	+0.70
6.	Bodwa	Bilara Limestone	0.72	1.68	+0.96	2.50	3.05	+0.55
7.	Arwar	Tertiary Sandstone	4.00	2.76	-1.24	3.00	2.01	-0.99
8.	Deu	Sandstone	4.00	2.00	-2.00	1.50	1.0	-0.50
9.	Barnel	Bilara Limestone	2.00	1.20	-80	1.40	1.02	-0.38
10.	Chajoli	Sandstone	1.84	3.80	+1.96	2.80	1.30	-1.50
11.	Kalvi	Older alluvium	1.68	2.80	+1.12	0.3	1.31	+1.01
12.	Roll	Bilara Limestone	2.48	1.95	-0.53	1.50	1.01	-0.49
13.	Boseri	Sandstone	2.56	1.72	-0.84	0.30	0.23	-0.07
14.	Jhun-Jala	Tertiary Sandstone	1.60	1.70	+0.10	1.20	0.90	-0.30
15.	Khanwar	Bilara Limestone	2.16	2.44	+0.28	0.50	0.40	-0.10
16.	Dugoli	Older alluvium	5.76	0.00	5.76	3.10	2.01	-1.09
17.	Pindia	Sandstone	0.88	2.00	+1.12	1.20	0.28	-0.92
18.	Khabriana	Older alluvium	1.60	0.00	1.60	2.50	1.10	-1.40
19.	Surpaliya	Older alluvium	1.44	0	1.44	0.50	0.60	+0.10
20.	Soneli	Bilara Limestone	4.00	2.8	-2.75	0.60	0.50	+0.10

Table 5. pH in Groundwater during pre and post -monsoon in the years 2009 and 2018

S. No	Well Location	Rock formation	Pre-monsoon(p.H)			Post-Monsoon (p.H)		
			Year (2009)	Year (2018)	Variation (2009-2018)	Year (2009)	Year (2018)	Variation (2009-2018)
1.	Jayal	Sandstone	7.9	8.3	+0.4	7.9	8.3	+0.4
2.	Jhareli	Sandstone	7.8	8.0	+0.2	7.8	8.0	+0.2
3.	Khatu-Kallan	Sandstone	7.8	8.2	+0.4	7.8	8.2	+0.4
4	Mundi	Tertiary Sandstone	7.8	8.3	+0.5	7.8	8.3	+0.5
5.	Tarnau	Older alluvium	7.9	8.3	+0.4	7.9	8.3	+0.4
6.	Bodwa	Bilara Limestone	7.9	8.2	+0.3	7.9	8.0	+0.1
7.	Arwar	Tertiary Sandstone	7.8	8.3	+0.5	7.8	8.2	+0.4
8.	Deu	Sandstone	7.9	8.5	+0.6	7.9	8.1	+0.2
9.	Barnel	Bilara Limestone	7.8	8.8	+1	7.8	8.0	+0.2
10.	Chajoli	Sandstone	7.8	8.0	+0.2	7.8	8.1	+0.3
11.	Kalvi	Older alluvium	7.8	8.0	+0.2	7.8	8.2	+0.4
12.	Roll	Bilara Limestone	7.8	8.4	+0.6	7.9	8.0	+0.1
13.	Boseri	Sandstone	7.9	8.6	+0.7	7.9	8.2	+0.3
14.	Jhun-Jala	Tertiary Sandstone	7.9	8.2	+0.3	7.9	8.1	+0.2
15.	Khanwar	BilaraLimestone	7.9	8.0	+0.1	7.9	8.2	+0.3
16.	Dugoli	Older alluvium	7.9	8.2	+0.3	7.9	8.1	+0.2
17.	Pindia	Sandstone	7.9	8.1	+0.2	7.9	8.0	+0.1
18.	Khabriana	Older alluvium	7.9	8.3	+0.4	7.8	8.1	+0.3
19.	Surpaliya	Older alluvium	7.9	8.1	+0.2	7.9	8.2	+0.3
20.	Soneli	Bilara Limestone	7.8	8.1	+0.3	7.8	8.0	+0.2

Table 6. Pre- and Post- monsoon Electrical Conductivity data of Jayal block (year 2009).

S.N	Well Location	Rock formation	Pre-monsoon (E.C (µS/cm)			Post-Monsoon (E.C. (µS/cm)		
			Year (2009)	Year (2018)	Variation (2009-2018)	Year (2009)	Year (2018)	Variation (2009-2018)
1.	Jayal	Sandstone	2730	3220	+490	2650	3150	+500
2.	Jhareli	Sandstone	1900	10400	+8500	15300	6415	-8885
3.	Khatu-Kallan	Sandstone	3900	5010	+1110	3100	4610	+1510
4	Mundi	Tertiary Sandstone	8800	5140	-3690	4900	3460	-1440
5.	Tarnau	Older alluvium	16300	600	-15700	9000	5546	-3454
6.	Bodwa	Bilara Limestone	1700	1522	-178	1830	1610	-220
7.	Arwar	Tertiary Sandstone	9100	7350	-1750	9500	8500	-1000
8.	Deu	Sandstone	3400	280	-3120	2700	2312	-388
9.	Barnel	Bilara Limestone	3600	1840	-1760	2000	1574	-426
10.	Chajoli	Sandstone	3100	3610	+510	3100	2955	-145
11.	Kalvi	Older alluvium	7600	6210	-1390	6200	5935	-265
12.	Roll	Bilara Limestone	6300	5566	-734	8600	6610	-1990
13.	Boseri	Sandstone	6700	3130	-3570	4800	3745	-1055

14.	Jhun-Jala	Tertiary Sandstone	5800	5900	+100	1800	1755	-45
15.	Khanwar	Bilara Limestone	6500	2580	-3920	7500	2690	-4810
16.	Dugoli	Older alluvium	7400	9000	+1600	12700	10900	-1800
17.	Pindia	Sandstone	6400	6410	+10	5900	5633	-267
18.	Khabriana	Older alluvium	3500	5010	+1510	9800	4865	-4935
19.	Surpaliya	Older alluvium	6800	7600	+800	5000	5535	+535
20.	Soneli	Bilara Limestone	2700	2500	-200	1200	1522	+322

Table 7. Pre- and Post- monsoons T.D.S. data of Jayal Block, year 2009.

S.No	Well Location	Rock formation	Pre-monsoon (T.D.S (mg/l)			Post-Monsoon (T.D.S. mg/l)		
			Year (2009)	Year (2018)	Variation (2009-2018)	Year (2009)	Year (2018)	Variation (2009-2018)
1.	Jayal	Sandstone	1744	1899	+155	1590	1650	+60
2.	Jhareli	Sandstone	1205	6240	+5035	9180	9565	+385
3.	Khatu-Kallan	Sandstone	1542	2818	+1276	1860	4662	+2802
4	Mundi	Tertiary Sandstone	4945	2856	-2089	2940	4410	+1470
5.	Tarnau	Older alluvium	5179	329	-4850	5400	678	-4722
6.	Bodwa	Bilara Limestone	934	1766	+832	1098	1510	+412
7.	Arwar	Tertiary Sandstone	5944	5522	-422	5700	4953	-747
8.	Deu	Sandstone	2040	190	-1850	1620	210	-1410
9.	Barnel	Bilara Limestone	2115	693	-1422	1200	325	-875
10.	Chajoli	Sandstone	1910	2052	+142	1860	1763	-97
11.	Kalvi	Older alluvium	7600	3492	-4108	3720	1546	-2174
12.	Roll	Bilara Limestone	6300	5643	-657	5160	5622	+1362
13.	Boseri	Sandstone	3734	1965	-1769	2880	1986	-894
14.	Jhun-Jala	Tertiary Sandstone	5800	5610	-190	10800	5600	-5200
15.	Khanwar	Bilara Limestone	6500	1493	-5007	4500	750	-3750
16.	Dugoli	Older alluvium	4410	5199	+789	7620	4985	-2635
17.	Pindia	Sandstone	6400	3662	-2738	3540	3255	-285
18.	Khabriana	Older alluvium	3500	2846	-654	5880	2549	-3431
19.	Surpaliya	Older alluvium	6800	4486	-2314	3000	4095	+1095
20.	Soneli	Bilara Limestone	2700	2400	-300	720	890	+170

Table 8. Pre- and Post- monsoon chloride data of Jayal block, year 2009.

S.No	Well Location	Rock formation	Pre-monsoon (Cl^{-1}(mg/l)			Post-Monsoon (Cl^{-1}(mg/l)		
			Year (2009)	Year (2018)	Variation (2009-2018)	Year (2009)	Year (2018)	Variation (2009-2018)
1.	Jayal	Sandstone	10.80	22.40	+11.60	6.80	11.78	+4.98
2.	Jhareli	Sandstone	4.20	103.00	+98.80	144.00	56.82	-78.18
3.	Khatu-allan	Sandstone	18.00	42.80	+24.80	18.00	33.40	+15.40
4	Mundi	Tertiary Sandstone	47.20	44.00	-3.20	36.00	56.22	+20.22

5.	Tarnau	Older alluvium	140.00	4.40	-135.60	78.40	6.09	-72.31
6	Bodwa	Bilara Limestone	4.40	50.14	+45.74	2.60	2.00	-0.60
7	Arwar	Tertiary Sandstone	68.00	66.00	-2.00	62.80	60.10	-2.70
8	Deu	Sandstone	10.00	2.00	-8.00	10.40	3.12	-7.28
9	Barnel	Bilara Limestone	19.60	4.60	15.00	5.80	4.56	-1.24
10	Chajoli	Sandstone	20.00	32.00	+12.00	11.20	27.60	+16.40
11	Kalvi	Older alluvium	53.20	52.80	-0.40	40.00	50.17	+10.17
12	Roll	Bilara Limestone	53.20	44.10	-9.10	48.00	41.33	-6.67
13	Boseri	Sandstone	46.00	17.60	-28.40	40.00	15.42	-24.58
14	Jhun-Jala	Tertiary Sandstone	41.20	27.30	-13.90	136.00	25.65	-110.35
15	Khanwar	Bilara Limestone	26.00	18.20	-7.80	46.80	17.50	-29.30
16	Dugoli	Older alluvium	50.00	82.00	+32.00	100.00	75.65	-24.35
17	Pindia	Sandstone	44.40	55.00	+10.60	48.40	50.69	+2.29
18	Khabriana	Older alluvium	4.40	45.80	+41.40	71.60	43.62	-27.98
19	Surpaliya	Older alluvium	40.00	70.00	+30.00	44.00	71.35	+27.35
20	Soneli	Bilara Limestone	6.60	22.56	15.96	0.80	21.35	+20.55

Table 9. Nitrate concentration in Groundwater during pre and post-monsoon 2009 and 2019.

S.No	Rock formation	Well Location	Pre-monsoon NO_3^{-1}(mg/l)			Post-Monsoon (NO_3^{-1}(mg/l)		
			Year (2009)	Year (2018)	Variation (2009-2018)	Year (2009)	Year (2018)	Variation (2009-2018)
1.	Sandstone	Jayal	2.96	0.46	-2.5	2.96	0.47	-2.49
2.	Sandstone	Jhareli	1.98	3.08	+1.10	3.22	3.08	-0.14
3.	Sandstone	Khatu-Kallan	3.70	0.30	3.40	3.70	0.30	-3.40
4	Tertiary Sandstone	Mundi	0.74	0.1	-0.63	0.70	0.1	0.60
5.	Older alluvium	Tarnau	3.46	0.1	-3.36	6.61	0.1	6.51
6.	Bilara Limestone	Bodwa	0.85	1.7	+0.85	1.12	1.5	+0.38
7.	Tertiary Sandstone	Arwar	2.17	0.56	-1.61	1.61	0.55	-1.06
8.	Sandstone	Deu	3.35	0.02	-3.33	1.20	0.03	-1.17
9.	Bilara Limestone	Barnel	1.29	0.40	-0.89	0.96	0.51	-0.40
10.	Sandstone	Chajoli	1.08	0.00	-1.08	1.13	0.00	-1.13
11.	Older alluvium	Kalvi	2.58	1.08	-1.50	0.88	1.50	+0.62
12.	Bilara Limestone	Roll	1.80	1.02	-0.78	4.03	1.32	-2.71
13.	Sandstone	Boseri	3.41	3.04	-0.37	5.80	3.68	-2.12
14.	Tertiary Sandstone	Jhun-Jala	0.51	0.12	-0.39	1.20	0.15	-1.05
15.	Bilara Limestone	Khanwar	1.77	0.00	-1.77	0.50	0.00	-0.50
16.	Older alluvium	Dugoli	7.80	1.21	-6.59	3.10	1.15	-1.95
17.	Sandstone	Pindia	3.95	0.09	-3.86	1.20	0.81	-0.39
18	Older alluvium	Khabriana	3.93	0.00	-3.93	2.50	0.00	-2.50
19.	Older alluvium	Surpaliya	1.87	2.42	+0.55	0.50	2.40	+1.90
20.	Bilara Limestone	Soneli	0.43	2.00	+1.57	0.60	0.65	0.05

Comparative Study of Chemical Properties of Groundwater between year 2009 and 2018.

There was marginally better rainfall in the year 2018 in comparison to the year 2009. Comparisons of post monsoon 2009 and 2018 values were considered so as to account for effect of rainfall in the area. In the year 2009, the rainfall was 228.0 and in the year 2018 the rainfall was 293.0 mm in Jayal block. It is observed that TDS values marginally decreases with increase in rainfall. The pH value is increased in the year 2018 with increase of rainfall. In the year 2009, pH values are less than 8.00 but in the year 2018 either it is 8.0 or more than 8.0. A chloride value does not show any clear trend after rainfall. In the year 2018, chloride content in 60% wells increased and 40% decreased. Nitrate content decreases in year 2018 in post monsoon period. Fluoride content increased in the year the 2018 except in well of Khatu-Kallan. Groundwater fluctuation data of Jayal Block are shown in table 1-9.

Correlation of fluoride concentration with other chemical Parameters

A correlation study amongst various chemical parameters indicates that TDS/EC followed by nitrate concentration in groundwater showed good correlation with fluoride concentration compared to other chemical parameters [9].In these studies, low values of hardness were observed for all the well samples. Generally, water with fluoride more than 1.5 mg/l has hardness less than 200 mg/l, which was found true in the present study also. The phenomenon of decrease in total hardness groundwater resulting to higher fluoride concentration may be attributed due to calcium complexing effect. Fluoride complexes are formed more readily in mineralized/saline water than in dilute/freshwater. Where fluoride and TDS are high, the chance of substitution by fluoride is less. Another factor significantly contributing to excess fluoride concentration in the groundwater may be attributed to the depletion in water table due to over-exploitation in the study area. On an average, lowering in ground water level at the rate of about 0.3m /year was observed in the study area which also contributing to ionic composition of groundwater.

WATER RELATED ISSUES AND MANAGEMENT

There is scarcity of surface water in the block area because of low and erratic rains, high potential evaporate-transpiration' and lack of perennial drainage system. There is incident of frequent drought like situations. Groundwater related issues of concern in the district is that most of the potential zones have witnessed heavy groundwater extraction causing lowering of groundwater levels and drying up of large number of shallow wells or reduction in their yields. Also block areas suffer from water quality problems and in some of the areas groundwater is highly saline and/or high fluoride concentration causing disease called fluorosis in human beings. There is need for supply side as well as demand side management in the block areas. Supply side management may include rainwater harvesting and aquifer recharge while demand side management may include growing water efficient crops, mandatory micro-irrigation and regulatory measures etc. as mentioned below:[1-9]

- Growing crops consuming lesser water may be encouraged incentivized and should be made mandatory in phased manner. This can save sizable volume of water, improve groundwater conditions and for developing irrigation facilities in additional areas.
- Salt resistant crops can be sown in the area having brackish to saline groundwater especially in coarse textured soil.
- To promote sprinkler and drip systems of irrigation using solar/wind energy and should be gradually declared as mandatory; which can save plenty of water especially groundwater resources in the area.
- Augmentation of groundwater resources by rainwater harvesting and artificial recharge techniques in suitable areas. IGNP water as a source of surface water for recharge may be explored;in addition to rainwater runoff. Rainwater harvesting by construction of structures like Tanka may be suitable structure in saline groundwater areas.
- 5. Installation of desalination plants using non-conventional energy (like solar, wind energy) in required villages is need of the hour.
- To encourage domestic/community de-fluoridation (using techniques of Nalgonda, activated alumina etc.) of groundwater for drinking purpose, wherever required. Increased Calcium rich and protein diet may also lower the adverse impact of fluorosis.
- Notification of block area for "over-exploited areas"and also for poor groundwater quality areas" by the Central Ground Water Authority "for effective enforcement of regulatory measures.
- Possibilities of bringing IGNP water may be explored
- Mass awareness, water literacy and community participation are needed for addressing various issues of concerned effectively and efficiently. Integrated participatory management of all stakeholders including scientists, academicians, engineers, industries, farmers and common man is need of the hour for implementation of various recommended management strategies formulated

based on outcome of scientific studies; which will be fruitful for improving local ecosystem, socio-economic scenario and contribution towards development of the arid areas of the state of Rajasthan.

CONCLUSIONS

Jayal block of arid Nagaur district witness acute water crisis owing to scanty rainfall, declining groundwater levels, depleting groundwater resources because of over-exploitation and inferior quality of groundwater due to enhanced salinity as well as high fluoride concentration. The management options for addressing various water related issues should include supply side as well as demand side management incorporating components of water conservation, groundwater augmentation (rainwater harvesting and artificial recharge to groundwater) and regulatory measures by notification of the block area.

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