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Groundwater Suitability for Irrigational Purpose in Hatkanagale Taluka, Kolhapur District, Maharashtra, India

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The groundwater suitability for irrigational purposes of Hatkanagale taluka (latitude 16°37' 11" N to 16° 54' 51" N and longitude 74°13'25" E to 74°28' 31" E) was carried out and 32 dug well water samples were collected. The chemical analysis of these water samples reveals that 100% groundwater samples of pre-monsoon season and 78% groundwater samples of post-monsoon season represent Ca+Mg>Na+K (alkaline earth exceed alkalies) hydrochemical facies, while 18% and 4% groundwater samples of post-monsoon season represent Na+K>Ca+Mg (alkalies exceed alkaline earth) and Ca+Mg (alkaline earths) hydrochemical facies respectively. Similarly, 87.5% groundwater samples of pre-monsoon season and 78% groundwater samples of post-monsoon season belong to $Cl+SO_4>HCO_3+CO_3$ (strong acid exceeds weak acid) hydrochemical facies, while 12.5% and 22% groundwater samples represent $Cl+SO_4$ (strong acid) hydrochemical facies in pre and post-monsoon seasons respectively. U. S. Salinity diagram of the groundwater samples belongs to C_2-S_1 to C_3-S_1 type and C_2-S_1 to C_3-S_2 type in pre and post-monsoon seasons respectively indicating medium to high salinity hazards. The values of Sodium Adsorption Ratio, Residual Sodium Carbonate, Magnesium hazards, Kelley's ratio and Chloride concentrations for both the seasons are within permissible limit, indicate that the quality of groundwater is excellent for irrigation. The Gibb's diagram shows chemistry of groundwater is controlled by evaporation dominance.

Key words: *Hatkanagale taluka, chemical parameters, groundwater, irrigational suitability*

Introduction

The Hatkanagale taluka covers an area of about 614.38 km² in Survey of India Toposheet No. 47 L/1, L/5 and L/6 and is bounded by latitude 16°37' 11" N to 16°54' 51" N and longitude 74°13'25" E to 74°28' 31" E **(Fig. 1).**

In the present study, the representative samples from 32 dug wells were collected, during pre-monsoon and post-monsoon seasons in 2007 **(Fig. 2)**. The chemical analyses of samples were carried out by procedure proposed by APHA, AWWA, WPCF (1992)[1] **(Table 1.a-b)**. pH and other physical parameters *viz.*, colour, odour, taste, turbidity and foam were analyzed immediately after collecting the water samples. Raghuwanshi and Thakur (2004)[2] carried out the study on surface and subsurface waters of Choral River Basin, Indore District, Madhya Pradesh, India. Panaskar, *et al* (2007)[3] carried out the assessment of groundwater quality of Nanded city, Maharashtra, India. Yadav and Sawant (2012)[4] has made an attempt to study suitability of groundwater for irrigation in the Sheri Nala Basin, Sangli District, Maharashtra, India.

Methodology

The standard procedures for estimation of water and wastewater were used for chemical analysis of groundwater samples[1]. The chemical analyses of dug well water samples are given in **Table 1.a-b**. To know the suitability of groundwater for irrigation purposes, the specifications laid down by Kelley, *et al* (1940)[5], Eaton (1950)[6], U.S. Salinity Laboratory Staff (1954)[7], Wilcox (1948)[8] and Paliwal (1972)[9] were used. These specifications are mainly based on chemical characters of groundwater and their effects on plant growth. The calculated values of these specifications are given in **Table 2.a-b**.

In order to understand the suitability of groundwater for irrigation, the ratios like Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Magnesium hazards, Kelley's ratio and Chloride concentrations are considered.

Sodium Adsorption Ratio (SAR)

The concentration of sodium is very important in classifying irrigation water because sodium by the process of base exchange replaces calcium in the soil thereby, reduces the permeability of soil and has greater effect on the plant

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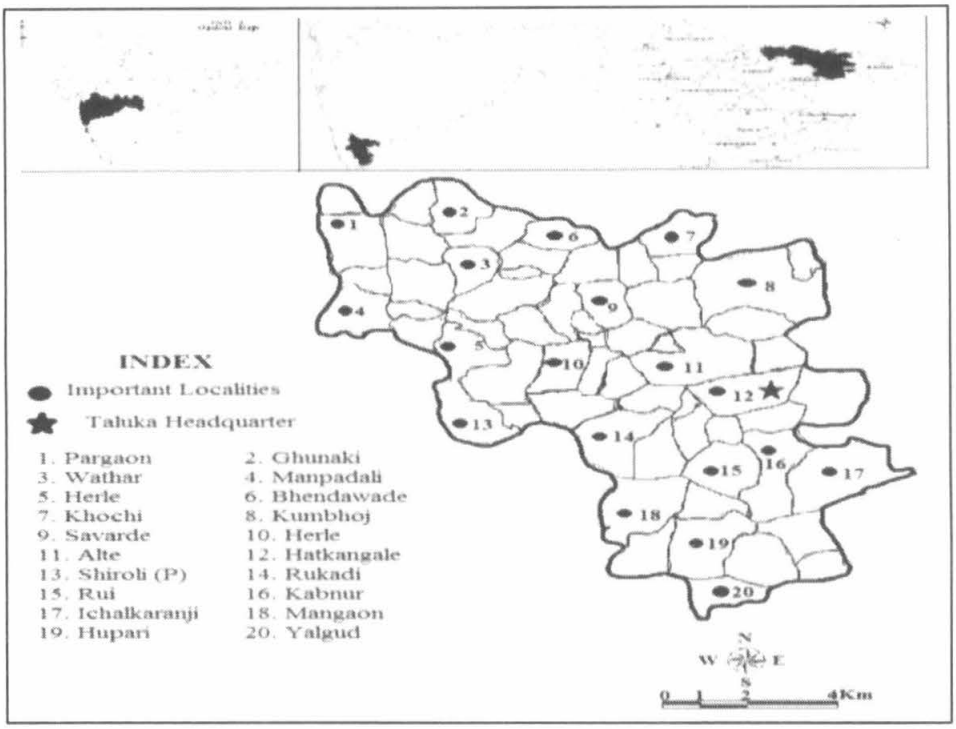

Fig.1: Locality map of the study area

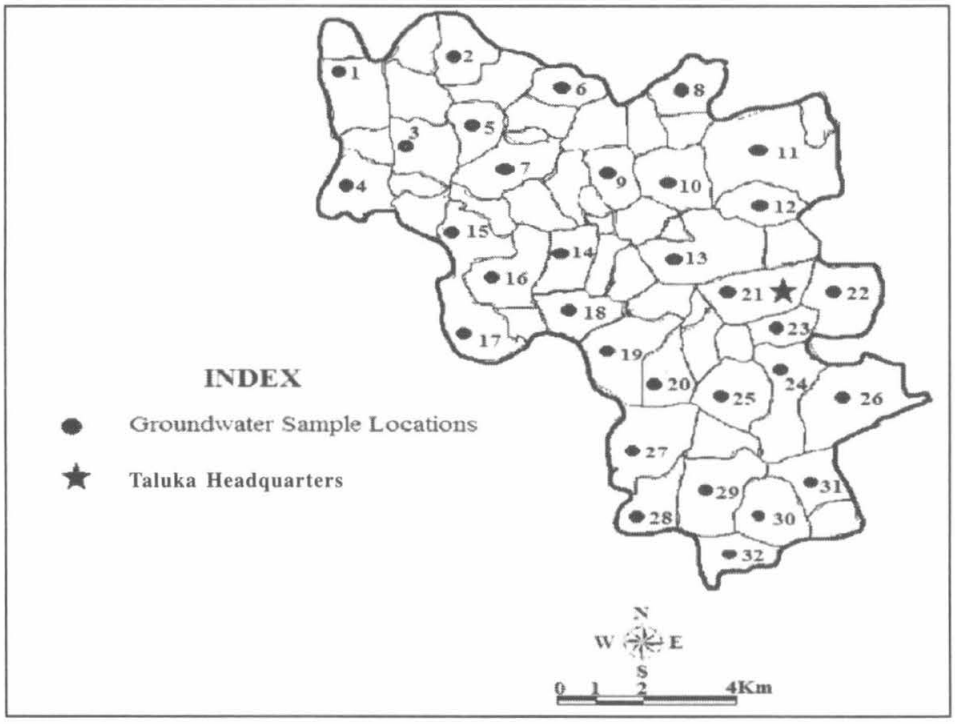

Fig. 2 : Sampling location map of the study area

Table 1a : Concentration of different chemical parameters of dug well water samples (pre-monsoon season)

Parameters/Sample Nos.	pH	EC	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl
DW 1	6.83	0.42	238.71	48.94	72.14	78.40	17.51	00	11.30	287.02
" 2	6.98	0.48	243.20	31.69	183.12	51.54	207.34	22.50	96.87	294.30
" 3	7.10	0.38	120.73	36.79	176.68	57.12	145.07	32.00	48.61	128.00
" 4	7.15	0.36	80.16	55.35	80.62	16.03	244.00	25.00	16.36	244.98
" 5	6.65	0.52	243.20	31.69	87.06	16.72	307.52	00	17.48	270.03
" 6	6.92	0.68	380.17	22.78	82.13	88.45	19.67	36.50	39.03	281.32
" 7	6.70	0.31	120.24	55.35	75.03	12.15	198.25	00	12.46	119.94
" 8	7.10	0.42	367.38	11.54	74.17	61.51	384.73	00	17.02	124.12
" 9	6.90	0.68	400.10	29.40	67.84	87.40	282.44	00	48.13	200.80
"10	6.88	0.74	386.43	135.98	92.25	35.63	32.15	25.00	13.48	1041.00
" 11	6.84	0.82	270.62	48.98	90.92	21.68	309.70	00	11.37	293.58
" 12	6.98	0.72	397.34	153.45	117.72	32.65	281.91	16.50	12.48	304.90
" 13	7.05	0.88	376.67	144.54	100.08	81.72	562.38	12.50	13.57	360.58
" 14	7.10	1.20	288.15	38.94	89.03	18.00	309.17	00	12.01	181.45
" 15	7.20	0.98	244.48	102.36	178.53	111.36	244.00	12.50	40.13	304.90
" 16	7.15	0.98	192.38	147.45	150.88	39.45	131.67	23.00	46.91	323.01
" 17	6.97	1.26	238.07	151.32	157.30	21.54	148.16	24.50	42.87	278.73
" 18	6.91	1.22	188.69	73.14	132.05	66.45	112.60	12.50	11.90	258.93
" 19	6.88	1.32	360.72	179.80	222.20	78.04	213.50	37.50	50.13	1094.60
" 20	6.80	1.47	400.80	165.90	230.18	70.20	305.00	25.00	53.13	994.60
" 21	6.72	0.98	355.10	95.56	238.06	68.11	18.75	21.50	52.72	881.85
" 22	6.60	1.32	240.48	110.66	180.68	44.18	305.00	12.50	48.67	594.81
" 23	6.65	1.47	261.03	39.56	83.21	42.89	28.98	00	14.78	306.67
" 24	6.78	1.28	331.71	63.19	91.68	10.92	26.19	23.50	16.51	379.65
" 25	6.89	1.40	291.30	149.22	198.56	37.71	326.11	27.50	15.83	361.00
" 26	6.94	1.28	240.64	37.27	103.96	38.98	110.47	00	19.37	342.03
"27	6.82	0.86	280.32	48.68	219.56	21.78	257.21	00	29.36	336.50
" 28	6.97	0.92	349.01	138.11	203.84	9.40	27.43	14.50	12.88	767.28
" 29	7.05	1.12	323.03	173.09	132.48	17.81	517.70	19.50	17.42	785.81
" 30	7.13	1.32	265.82	48.75	138.78	47.49	305.12	00	46.20	297.36
" 31	6.98	1.18	278.17	123.56	76.25	18.21	213.38	26.00	36.96	310.20
" 32	7.09	1.38	322.87	32.56	83.92	38.72	294.80	00	33.53	224.87

DW = Dug Well
EC = Electrical Conductivity (in mmho/cm)
pH : in log of H^+ concentration
Ca, Mg, Na, K, HCO_3, CO_3, SO_4, Cl : in ppm

growth. The relative activity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as Sodium Adsorption Ratio.

$$SAR = \frac{Na}{\sqrt{Ca + Mg/2}}$$

The SAR values varied from 0.881 epm to 3.620 epm in pre-monsoon season, whereas, in the post-monsoon season, it varied from 0.904 epm to 7.876 epm.

Residual Sodium Carbonate (RSC)

The water having carbonate and bicarbonate ions in excess of Ca and Mg will lead more alkali formation which is indicated by SAR and thereby decreasing the soil permeability[6]. The indirect effect of CO_3 and HCO_3 on water quality is expressed as Residual Sodium Carbonate.

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

The RSC values from -29.110 epm to -3.730 epm in pre-monsoon season, whereas, for the post-monsoon season, RSC values varied from -14.670 epm to 7.970 epm.

Table 1.b : Concentration of different chemical parameters of dug well water samples (post-monsoon season)

Parameters/Sample Nos.	pH	EC	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl
DW 1	7.08	0.42	238.71	48.94	72.14	78.40	17.51	00	11.30	287.02
" 2	8.20	0.48	243.20	31.69	183.12	51.54	207.34	22.50	96.87	294.30
" 3	7.48	0.38	120.73	36.79	176.68	57.12	145.07	32.00	48.61	128.00
" 4	7.85	0.36	80.16	55.35	80.62	16.03	244.00	25.00	16.36	244.98
" 5	7.62	0.52	243.20	31.69	87.06	16.72	307.52	00	17.48	270.03
" 6	7.14	0.68	380.17	22.78	82.13	88.45	19.67	36.50	39.03	281.32
" 7	8.00	0.31	120.24	55.35	75.03	12.15	198.25	00	12.46	119.94
" 8	7.10	0.42	367.38	11.54	74.17	61.51	384.73	00	17.02	124.12
" 9	7.35	0.68	400.10	29.40	67.84	87.40	282.44	00	48.13	200.80
" 10	8.12	0.74	386.43	135.98	92.25	35.63	32.15	25.00	13.48	1041.00
" 11	6.25	0.82	270.62	48.98	90.92	21.68	309.70	00	11.37	293.58
" 12	6.78	0.72	397.34	153.45	117.72	32.65	281.91	16.50	12.48	304.90
" 13	7.78	0.88	376.67	144.54	100.08	81.72	562.38	12.50	13.57	360.58
" 14	7.01	1.20	288.15	38.94	89.03	18.00	309.17	00	12.01	181.45
" 15	6.54	0.98	244.48	102.36	178.53	111.36	244.00	12.50	40.13	304.90
" 16	6.89	0.98	192.38	147.45	150.88	39.45	131.67	23.00	46.91	323.01
" 17	6.99	1.26	238.07	151.32	157.30	21.54	148.16	24.50	42.87	278.73
" 18	7.26	1.22	188.69	73.14	132.05	66.45	112.60	12.50	11.90	258.93
" 19	7.11	1.32	360.72	179.80	222.20	78.04	213.50	37.50	50.13	1094.60
" 20	7.20	1.47	400.80	165.90	230.18	70.20	305.00	25.00	53.13	994.60
" 21	7.56	0.98	355.10	95.56	238.06	68.11	18.75	21.50	52.72	881.85
" 22	6.70	1.32	240.48	110.66	180.68	44.18	305.00	12.50	48.67	594.81
" 23	6.10	1.47	261.03	39.56	83.21	42.89	28.98	00	14.78	306.67
" 24	8.25	1.28	331.71	63.19	91.68	10.92	26.19	23.50	16.51	379.65
" 25	7.22	1.40	291.30	149.22	198.56	37.71	326.11	27.50	15.83	361.00
" 26	7.09	1.28	240.64	37.27	103.96	38.98	110.47	00	19.37	342.03
" 27	6.53	0.86	280.32	48.68	219.56	21.78	257.21	00	29.36	336.50
" 28	7.10	0.92	349.01	138.11	203.84	9.40	27.43	14.50	12.88	767.28
" 29	6.70	1.12	323.03	173.09	132.48	17.81	517.70	19.50	17.42	785.81
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" 31	7.56	1.18	278.17	123.56	76.25	18.21	213.38	26.00	36.96	310.20
" 32	6.78	1.38	322.87	32.56	83.92	38.72	294.80	00	33.53	224.87

DW = Dug Well
EC = Electrical Conductivity (in mmho/cm)
pH : in log of H^+ concentration
Ca, Mg, Na, K, HCO_3, CO_3, SO_4, Cl : in ppm

Magnesium hazards

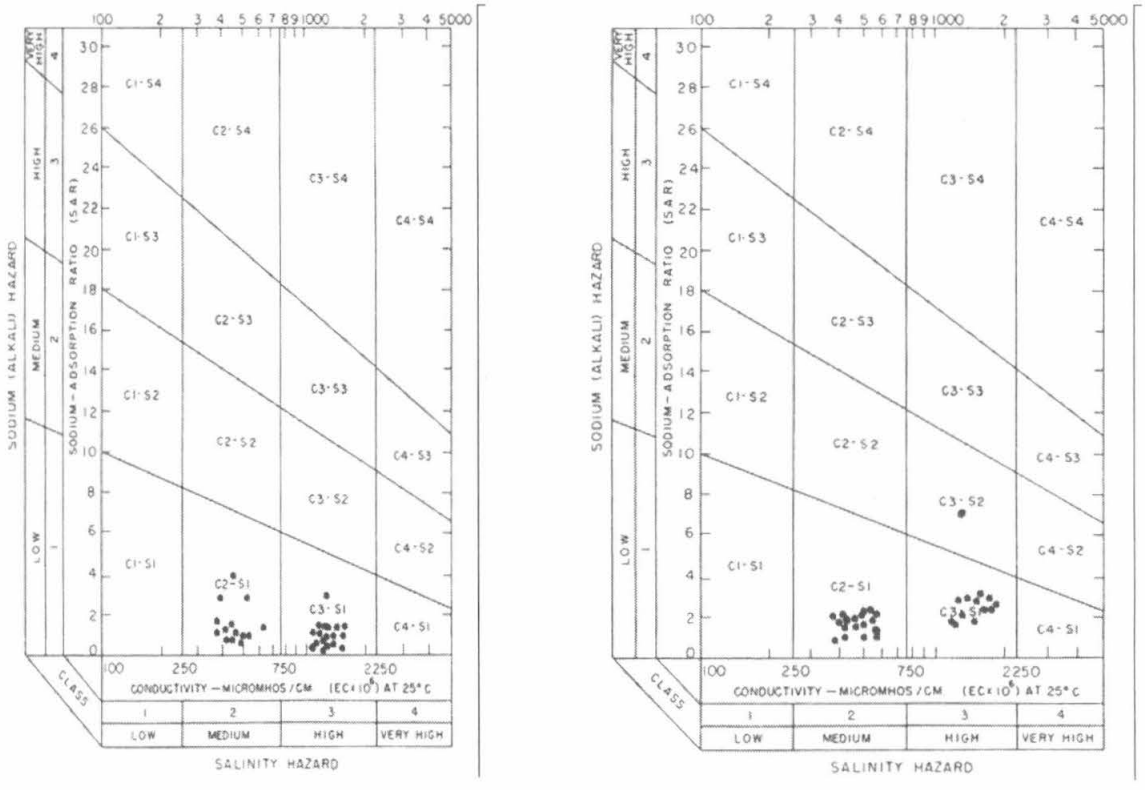
Paliwal (1972)[9] has used the ratio Mg x 100 / Ca + Mg as an index of magnesium hazards for irrigation water. The magnesium ratio for groundwater samples of the study area varied from 4.558 epm to 89.156 epm in pre- monsoon season, whereas, for the post-monsoon season, magnesium ratio varied from 4.534 epm to 96.464 epm.

Kelley's Ratio (KR)

The water used for irrigational purpose, the sodium problem can be worked out by the values of Kelley's ratio[5].

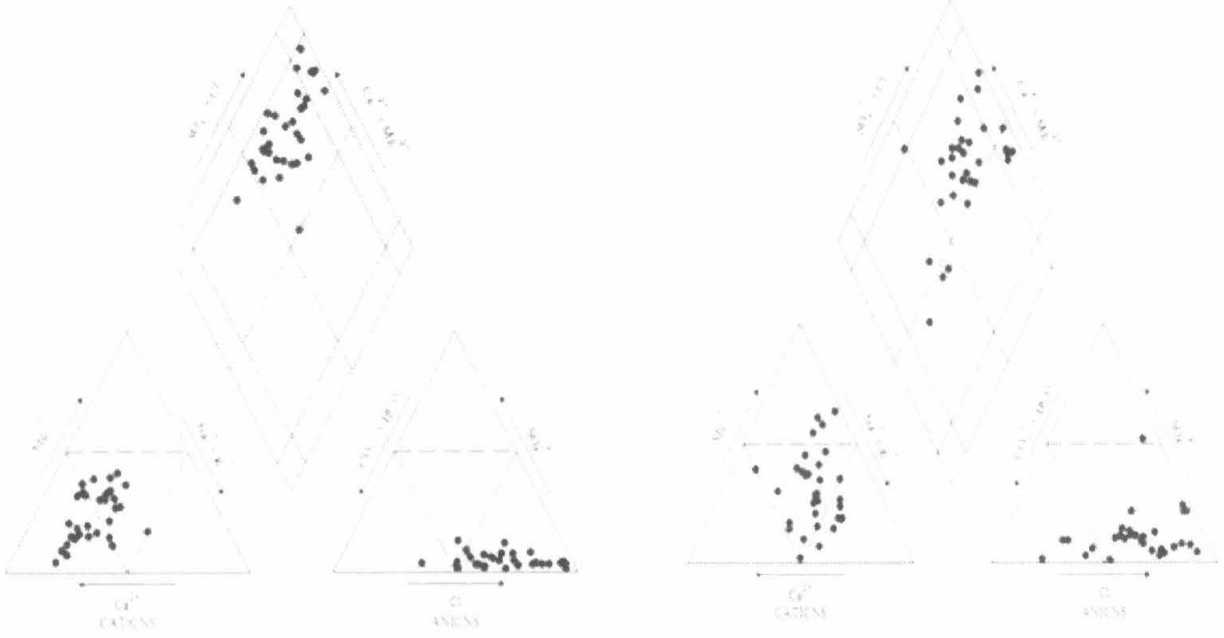
$$\text{Kelley's ratio} = \frac{Na}{Ca + Mg}$$

The Kelley's ratio calculated for groundwater samples of the study area varied from 0.131 epm to 0.850 epm in pre-monsoon season, whereas, for the post-monsoon season, Kelley's ratio varied from 0.112 epm to 1.734 epm.



a.Pre-monsoon season b. Post-monsoon season

Fig. 3:Diagram for classification of irrigation waters (after Richard's)



a.Pre-monsoon season b. Post-monsoon season

Fig.4: Piper Trilinear diagram for classification of groundwater

Table 2.a: Irrigational specification values of bore well samples for pre-monsoon season

Parameters/Sample Nos.	SAR	RSC	Mg hazards	Kelley's ratio	SSP
DW 1	1.112	-15.650	25.282	0.196	22.920
" 2	2.935	-10.600	17.694	0.540	37.946
" 3	3.620	-5.600	33.480	0.850	49.469
" 4	1.697	-3.730	53.271	0.410	30.967
" 5	1.396	-9.700	17.639	0.257	21.886
" 6	1.105	-19.300	8.973	0.171	20.488
" 7	1.423	-7.310	43.181	0.309	25.000
" 8	1.000	-14.530	4.558	0.154	17.693
" 9	0.881	-17.760	10.808	0.131	17.441
" 10	1.027	-29.110	36.724	0.131	13.462
" 11	1.337	-12.450	22.989	0.225	20.063
" 12	1.271	-27.290	38.909	0.157	15.137
" 13	1.113	-21.050	38.742	0.142	16.421
" 14	1.305	-12.510	18.202	0.220	19.431
" 15	2.420	-16.200	40.834	0.376	32.746
" 16	1.993	-18.810	55.841	0.302	25.317
" 17	1.963	-21.090	51.191	0.281	23.047
" 18	2.069	-13.170	38.989	0.372	31.499
" 19	3.357	-11.850	89.156	0.582	40.416
" 20	2.438	-27.820	40.564	0.297	25.354
" 21	2.896	-24.560	30.754	0.404	31.467
" 22	2.419	-15.680	43.127	0.372	29.336
" 23	1.268	-15.810	20.012	0.222	21.607
" 24	1.210	-20.540	23.908	0.183	16.217
" 25	2.360	-20.550	45.786	0.322	25.972
" 26	1.647	-13.260	20.371	0.299	26.054
" 27	3.184	-17.700	22.234	0.530	35.704
" 28	2.337	-24.910	39.492	0.308	23.936
" 29	1.481	-27.340	46.921	0.189	14.423
" 30	2.055	-13.270	23.219	0.349	28.871
" 31	0.957	-18.140	42.286	0.138	13.302
" 32	1.190	-18.470	14.262	0.194	19.113

Soluble Sodium Percentage (SSP)

Wilcox (1955)[10] has classified irrigation water on the basis of Electrical Conductance (EC) and Soluble Sodium Percentage (SSP).

$$SSP = \frac{(Na + K) \times 100}{Ca + Mg + Na + K}$$

where, all concentrations are expressed in epm.

The values of SSP were determined for groundwater samples of the study area, which varied from 13.302 epm to 49.469 epm in pre-monsoon season, whereas, for the post-monsoon season, varied from 10.502 epm to 64.509 epm.

Discussion

The groundwater of the study area has been evaluated on the basis of above cited criteria. The frequency distributions of all irrigational parameters are given in **Table 3**. The salinity and sodium hazards have been evaluated by using the Kelley's ratio and SAR. If the Kelley's ratio is less than unity in all the dug well water samples indicates their suitable nature. Except the water sample nos. 2, 3, 4, 5, 6, 10, 11, 26, 27 and 30 in post-monsoon season all the other samples in pre and post-monsoon seasons are suitable for the growth of crops. The groundwater of the study area does not have bicarbonate hazards, as per Eaton's classification. However, water sample no. 6 in post-monsoon season has RSC values observed in between 1.25 to 2.5, which indicates their marginal nature for irrigational purposes. However, water sample nos.

Table 2.b: Irrigational specification values of bore well samples for post-monsoon season

Parameters/Sample Nos.	SAR	RSC	Mg hazards	Kelley's ratio	SSP
DW 1	2.245	-1.210	50.000	0.696	41.964
" 2	3.543	-3.180	45.000	1.252	56.756
" 3	3.602	7.970	33.333	1.242	57.055
" 4	3.921	-5.110	53.571	1.171	55.590
" 5	3.698	-3.710	45.000	1.307	58.506
" 6	3.358	1.750	16.000	1.062	54.254
" 7	2.375	2.950	58.333	0.766	52.522
" 8	2.529	-2.560	4.534	0.873	48.335
" 9	2.009	-4.690	23.333	0.580	37.759
" 10	7.876	-5.300	57.904	1.734	64.509
" 11	3.813	4.020	47.504	1.082	53.965
" 12	2.151	-9.840	56.386	0.424	33.229
" 13	2.146	-8.510	56.228	0.446	31.516
" 14	2.763	-4.700	31.697	0.883	49.326
" 15	2.261	-7.120	74.917	0.529	37.077
" 16	2.227	-9.230	96.464	0.474	33.833
" 17	1.834	-11.750	75.994	0.351	28.033
" 18	2.132	-2.320	70.485	0.664	48.345
" 19	0.904	-14.670	43.820	0.112	10.502
" 20	1.771	-13.620	40.062	0.313	24.705
" 21	2.120	-9.240	49.561	0.423	31.458
" 22	2.288	-0.230	69.356	0.501	34.937
" 23	2.354	-2.980	41.379	0.644	41.129
" 24	1.821	-6.410	34.417	0.376	33.027
" 25	1.959	-13.310	70.084	0.340	28.380
" 26	3.344	-4.060	48.598	1.142	55.042
" 27	3.581	-4.930	54.128	1.084	54.240
" 28	1.959	-5.980	56.534	0.426	36.576
" 29	2.234	-13.940	76.811	0.380	28.895
" 30	3.992	-5.110	53.571	1.192	55.801
" 31	1.557	-9.530	75.959	0.318	26.503
" 32	2.594	-4.200	19.188	0.787	45.962

3, 7, 11 in post-monsoon season have RSC values more than 2.5, which indicates their unsuitable nature for irrigational purposes. The high values of RSC in the water samples in the study area may be due to their circulation in basaltic lava flows. The calcium ions are liberated on the weathering of plagioclase feldspar and pyroxene. Therefore, calcium ions have formed complexes with available HCO_3 rather than hydroxide and carbonate. High values of RSC do not indicate its unsuitable nature; however, such water is restricted to be utilized for sensitive crops. The values of Mg hazards for water sample nos. 4, 16 and 17 in pre-monsoon season and water sample nos. 1, 4, 7, 10, 12, 13, 27, 28 and 30 in post-monsoon season ranged in 50 to 60%, which is marginal for irrigation purpose. Whereas, water sample no. 19 in pre-monsoon season and water sample nos. 15, 16, 17, 18, 22, 25, 29 and 31 in post-monsoon season had Mg hazards >65%, which is unsuitable for irrigational use. The values of soluble sodium percentage in water sample no.10 for post-monsoon season ranged between 60 to 80, which is doubtful for its irrigational application, whereas, all other samples in pre-monsoon and post-monsoon seasons fall in excellent to permissible category.

The values of EC varied from 0.31 mmho/cm to 1.47 mmho/cm in pre-monsoon season, whereas, for the post-monsoon season, EC values varied from 0.31mmho/cm to 1.47 mmho/cm. The U. S. Salinity Laboratory Staff (1954)[7] have proposed a diagram for classifying irrigational water with reference to alkali and salinity hazards. The values of Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) for all samples of the area are plotted in U. S. Salinity Laboratory

Staff diagram (**Fig. 3 a** and **3b**). **Fig. 3a and 3b** reveal that the 43.75% and 59.50% groundwater samples in pre and post-monsoon season fall in C_2-S_1 category, while 56.25% and 37.25% groundwater samples fall in C_3-S_1 category suggesting that the groundwater is of good quality. Whereas, 3% groundwater samples in post-monsoon season represent C_3-S_2 category indicating moderate quality of groundwater.

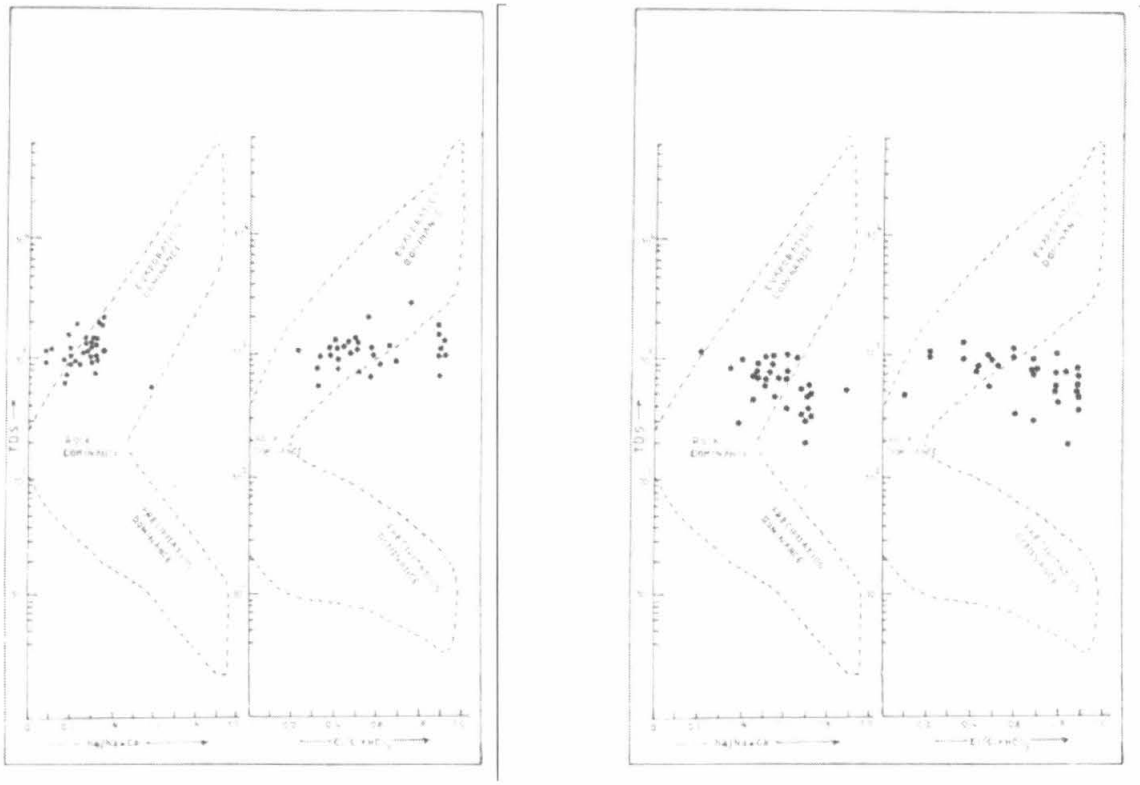
In order to understand the variation in hydrochemical facies with space and time the data has been plotted on the Piper Trilinear diagram[11] (**Fig. 4a and 4b**). It is observed from the **Fig. 4a** that 100% groundwater samples (32 samples) of pre-monsoon season represent Ca+Mg>Na+K (alkaline earth exceed alkalies) hydrochemical facies. Similarly, 87.5% groundwater samples (28 samples) belong to Cl+oSO_4>HCO_3+CO_3 (strong acid exceeds weak acid) hydrochemical facies and 12.5% groundwater samples (4 samples) represent Cl+SO_4 (strong acid) hydrochemical facies in pre-monsoon season.

From the **Fig. 4.b** it is seen that 78% groundwater samples (25 samples) represent Ca+Mg>Na+K(alkaline earth exceed alkalies) hydrochemical facies, while 18% (6 samples) and 4% (1 sample) groundwater samples of post-monsoon season represent Na+K>Ca+Mg (alkalies exceed alkaline earth) and Ca+Mg (alkaline earths) hydrochemical facies respectively. Similarly, 78% groundwater samples (25 samples) of post-monsoon season belong to Cl+SO_4>HCO_3+CO_3 (strong acid exceeds weak acid) hydrochemical facies, while 22% groundwater samples (7 samples) represent Cl+SO_4 (strong acid) hydrochemical facies in post-monsoon season.

The Gibb's variation diagram shows chemistry of groundwater is controlled by evaporation dominance [12] (**Fig. 5a** and **5b**).

Table 3: Frequency distribution of SAR, RSC, Mg hazards, Kelley's ratio, salinity hazards and SSP

Water quality parameters	Range	Water classes	Dug Wells			
			Pre-monsoon season		Post-monsoon season	
			No. of samples	%	No. of samples	%
U. S. Salinity diagram	C_1S_1	Good	——	—	——	——
	C_2S_1	Good	14	43.75	19	59.50
	C_3S_1	Good	18	56.25	12	37.50
	C_4S_1	Good	——	—	——	——
	C_3S_2	Moderate	—		01	03.00
	C_4S_2	Moderate	——	—	——	——
	C_3S_3	Moderate	——	—	——	——
	C_4S_3	Moderate	——	—	——	——
SAR	<10	Excellent	32	100	32	100
	10-18	Good	——	—	——	——
	18-26	Fair	——	—	——	——
	>26	Unsuitable	——	—	——	——
RSC	<1.25	Safe	32	100	28	87.50
	1.25 to 2.50	Marginal	—	——	01	03.12
	>2.50	Unsuitable	—	——	03	09.38
Mg hazards	<50%	Suitable	28	87.50	15	46.88
	50 to 60%	Marginal	03	09.38	09	28.12
	>60%	Unsuitable	01	03.12	08	25.00
Kelley's ratio	<1	Suitable	32	100	22	68.75
	1 to 2	Marginal	—	—	10	31.25
	>2	Unsuitable	—	—	—	—
SSP	<20	Excellent	10	31.25	01	03.12
	20 to 40	Good	20	62.50	14	43.75
	40 to 60	Permissible	02	06.25	16	50.00
	60 to 80	Doubtful	—	—	01	03.12
	>80	Unsuitable	—	—	—	——



a.Pre-monsoon season b. Post-monsoon season

Fig.5: Gibb's diagram for mechanism controlling groundwater chemistry

Conclusion

The groundwater samples in pre-monsoon and post-monsoon seasons are C_2-S_1 to C_3-S_1 type and C_2-S_1 to C_3-S_2 type respectively, indicating medium to high salinity hazards. The dominant hydrochemical facies observed in the study area are Ca+Mg>Na+K and Cl+SO_4>HCO_3+CO_3. The other facies observed are Na+K>Ca+Mg, Ca+Mg and Cl+SO_4

The Gibb's variation diagram suggests the chemistry of groundwater is evaporation dominant. The values of Sodium Absorption Ratio(SAR), Residual Sodium Carbonate(RSC), Mg hazards, Kelley's Ratio (KR) and Soluble Sodium Percentage (SSP) for both the seasons were within permissible limit, which indicates that the quality of groundwater is excellent for irrigation.

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