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Suitability of Ground Water for Irrigation in the Sheri Nala Basin, Sangli District, Maharashtra, India

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Abstract: The Sheri nala basin (latitude 16º50′05″ N to 16º54′45″ N and longitude 74º33′20″ E to 74º38′30″ E) in Sangli District, Maharashtra, has been taken up for evaluation to find the suitability of ground water for irrigation and its effect on the growth of plants on the basis of chemical analysis of ground water. The chemical parameters, viz., sodium adsorption ratio (SAR), residual sodium carbonate (RSC), magnesium hazards, Kelley's ratio and chloride concentrations were estimated to know the suitability of water for the irrigation purposes.

Key words: Sheri nala, chemical parameters, ground water, irrigational suitability.

Introduction

The Sheri nala basin (latitude 16º50′05″ N to 16º54′45″ N and longitude 74º33′20″ E to 74º38′30″ E) covers an area of about 56 km^2 (Figure 1). It is included in the Survey of India Toposheet No. 47 L/9. The basin is a sub-basin of river Krishna in Sangli District, Maharashtra. It shows dendritic to sub-parallel type of drainage pattern. For systematic investigation, the area has been divided into five sub-basins, viz., Madhavnagar (I), Kupwad (II), Budhgaon (III), Sangli (IV) and Padmale (V) (Figure 2).

In the present study, 25 dug wells and 50 bore wells samples were collected, during the pre monsoon and post monsoon periods of 2004 (Figure 3).

The chemical analysis of samples were carried out by procedure laid down by APHA, AWWA, WPCF (1992) (Table 1 [a to d]).The measurement of pH and other physical parameters, viz., colour, odour, taste, turbidity and foam were carried out immediately after collecting the water samples.

Vijayaram (1989) carried out the pollution studies of ground water in Sembattu, Trichy in relation to waste disposals and reported that most of the groundwater samples are not suitable for the purpose of drinking and industrial utilization. Pawar (1997) carried out the study on groundwater pollution in Pune. Sawant and Joshi (1999) carried out the study on bore well water pollution in Solapur city. Raghuwanshi and Thakur (2004) carried out the study on surface and subsurface waters of Choral river basin, Indore District, Madhya Pradesh, India.

Geology

The area is covered by the deccan basaltic lava flows. About 90% of the basin is covered by black cotton soil and alluvium and about 10% of the basin is covered by weathered brecciated murrum (Figure 4).

Methodology

The standard procedures for the estimation of water and waste water (APHA, AWWA and WPCF, 1992) were used for the chemical analysis of 75 representative samples (Table 1 [a to d]).

In order to know the suitability of groundwater for irrigation purposes, the specification proposed by Kelley et al. (1940), Eaton (1950), U.S. Salinity Laboratory Staff (1954), Wilcox (1948) and Paliwal (1972) were used.

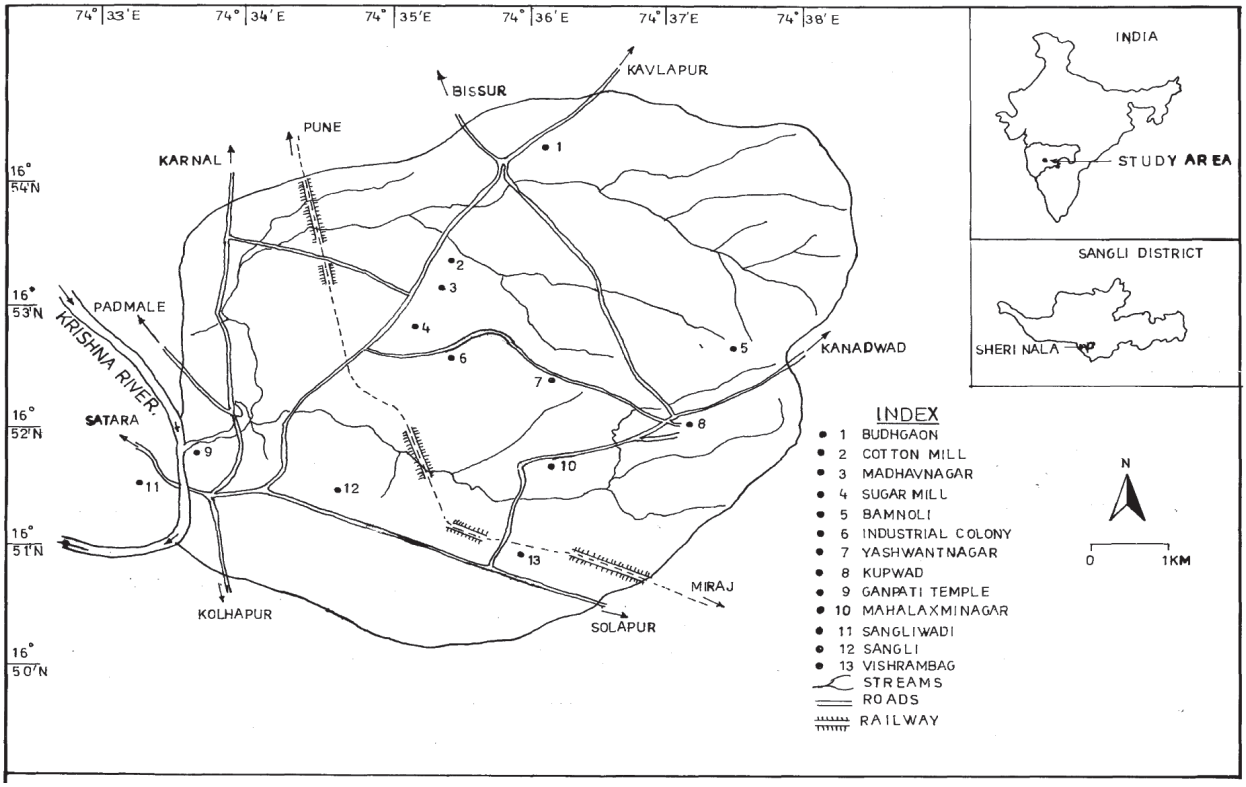


Figure 1: Locality map.

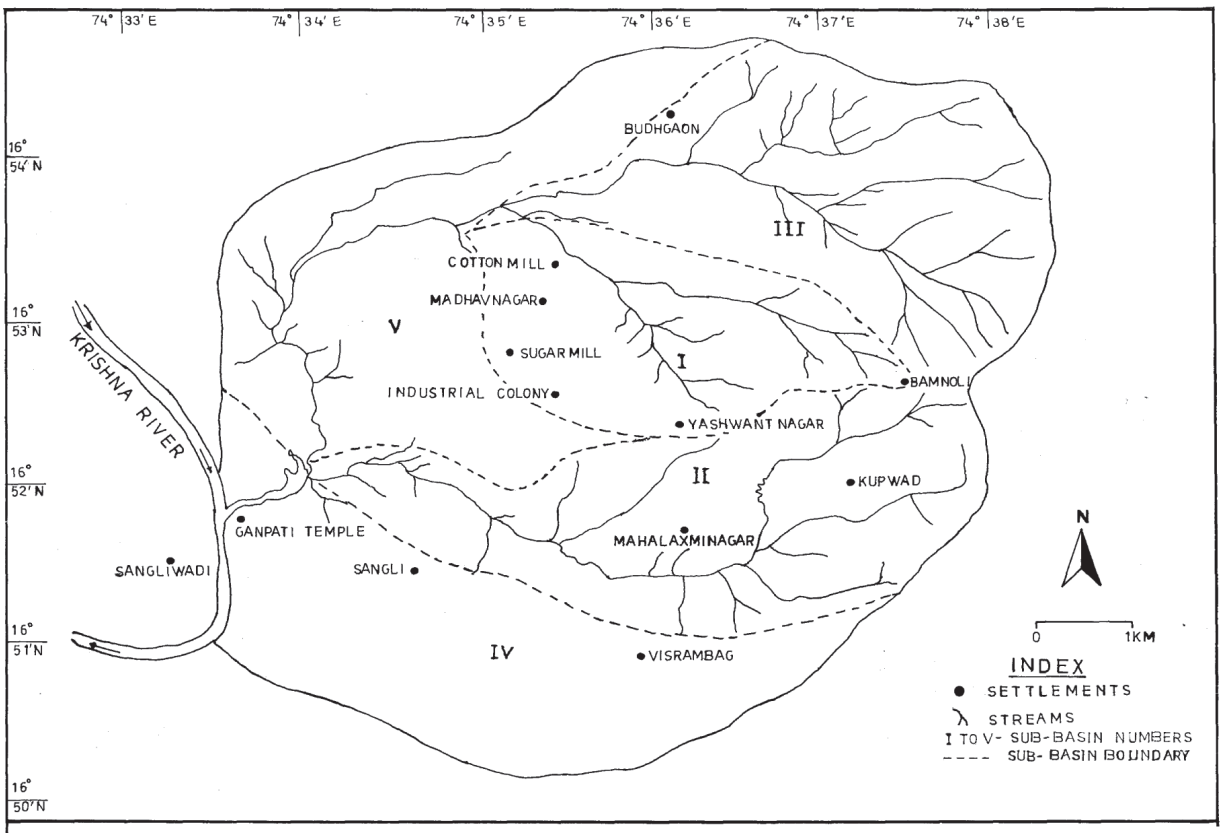


Figure 2: Drainage map of the basin.

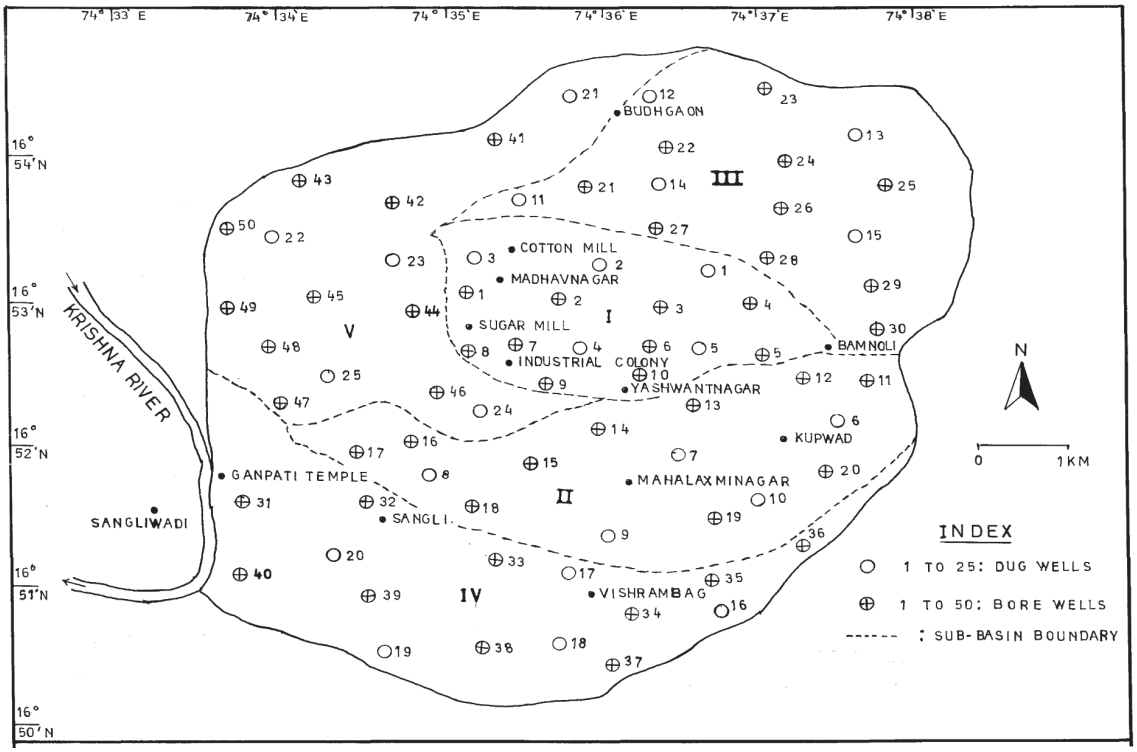


Figure 3: Sample location map.

Table 1a: Concentration of different chemical parameters of dug well water of sub-basin numbers I to V for the pre-monsoon period

Sub-basin numbers	*Parameter/ sample numbers*	*pH*	*EC*	*Ca*	*Mg*	*Na*	*K*	*HCO_3*	*CO_3*	*SO_4*	*Cl*
I	DW 1	7.21	2620	32	12	320	6.8	328	0.8	68	285
	" 2	7.50	2480	28	13	200	7.9	358	00	72	268
	" 3	7.58	2240	68	28	210	8.2	289	00	80	305
	" 4	7.22	2580	34	14	310	6.5	320	00	63	20
	" 5	7.48	2320	26	25	280	7.3	345	0.5	78	275
II	" 6	7.43	541	56	17	25	1.5	234	00	41	34
	" 7	7.33	1750	66	15	112	2.5	268	00	72	200
	" 8	7.21	2560	72	19	118	3.2	289	00	68	198
	" 9	7.38	560	58	18	23	1.4	231	00	38	195
	" 10	7.20	1722	70	16	115	2.2	255	0.1	65	201
III	" 11	7.95	3500	240	110	240	4.0	387	2.64	222	625
	" 12	7.80	2780	90	28	205	4.2	358	00	60	400
	" 13	7.56	2650	92	32	201	4.9	360	00	52	325
	" 14	7.82	2820	98	108	208	4.8	365	00	210	610
	" 15	7.64	2560	190	35	215	4.1	348	0.2	68	408
IV	" 16	7.07	1456	224	34	68	6.0	400	00	80	186
	" 17	7.75	860	95	23	34	4.0	177	00	115	78
	" 18	7.61	1920	92	35	109	3.8	258	00	68	205
	" 19	7.05	1430	212	43	39	8.0	405	00	89	99
	" 20	7.68	960	98	28	105	7.0	208	00	102	196
V	" 21	7.68	2150	94	32	118	6.6	299	00	42	268
	" 22	7.77	2080	98	22	168	7.2	305	00	68	299
	" 23	7.51	1970	86	30	205	6.5	427	0.8	78	262
	" 24	7.52	2060	95	25	115	6.9	295	00	41	253
	" 25	7.43	1868	84	31	202	7.8	320	0.1	65	240

Table 1b: Concentration of different chemical parameters of dug well water of sub-basin numbers I to V for the post monsoon period

Sub-basin numbers	*Parameters/ sample numbers*	*pH*	*EC*	*Ca*	*Mg*	*Na*	*K*	*HCO_3*	*CO_3*	*SO_4*	*Cl*
I	DW 1	7.61	1980	66	20	215	5.8	223	00	67	200
	” 2	7.15	1650	89	22	268	6.2	420	00	79	168
	” 3	7.50	1860	98	18	305	7.8	368	00	63	178
	” 4	7.58	1680	65	28	218	6.1	252	00	74	218
	” 5	7.20	1740	87	15	301	7.4	314	0.1	69	192
II	” 6	7.68	3150	83	17	309	3.6	268	1.0	62	192
	” 7	7.58	2860	68	16	296	3.9	320	00	69	200
	” 8	7.15	2780	33	22	308	4.2	401	1.2	78	218
	” 9	7.30	2890	82	14	306	3.3	265	00	68	206
	” 10	7.48	2760	66	25	292	3.8	328	00	73	228
III	” 11	7.25	1100	38	17	302	6.8	420	00	80	200
	” 12	7.48	1800	68	16	300	4.9	368	00	35	268
	” 13	7.33	2180	29	19	268	3.9	377	1.2	60	198
	” 14	7.15	1220	35	18	308	6.5	366	00	82	252
	” 15	7.30	1740	59	15	290	4.8	372	0.1	39	189
IV	” 16	6.99	2500	32	15	260	2.5	366	0.2	82	206
	” 17	7.02	2800	39	20	212	9.0	266	00	79	219
	” 18	7.31	2989	28	10	228	3.9	258	1.1	68	305
	” 19	6.88	2460	33	21	268	8.5	255	00	64	209
	” 20	7.28	2820	25	17	215	4.8	261	0.2	81	232
V	” 21	7.56	550	82	15	28	2.0	173	00	107	52
	” 22	6.85	1906	348	20	145	6.0	296	00	170	380
	” 23	7.44	2200	89	28	185	7.0	268	00	220	62
	” 24	7.48	1920	84	22	138	2.2	178	0.1	160	304
	” 25	6.90	2180	95	27	168	6.3	290	00	205	190

DW = Dug well
EC = Electrical conductivity (in µmho/cm)
pH in log of H^+ concentration
Ca, Mg, Na, K, HCO_3, CO_3, SO_4, Cl in ppm

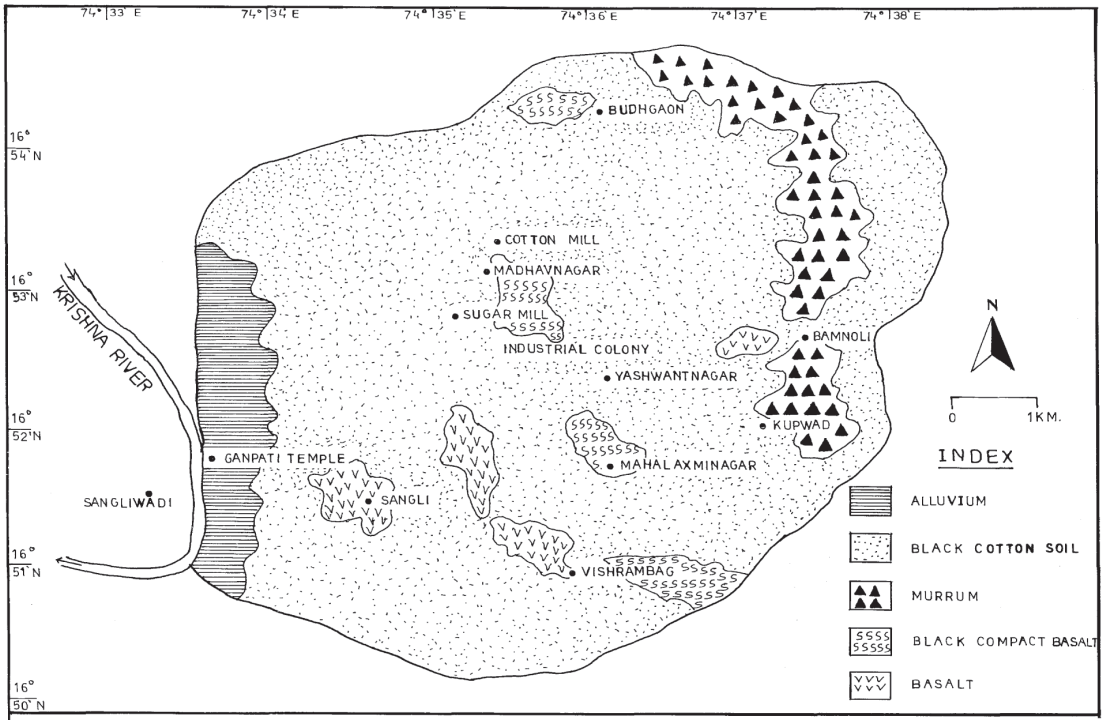


Figure 4: Geological map of the basin.

Table 1c: Concentration of different chemical parameters of bore well water of sub-basin numbers I to V for the pre monsoon period

Sub-basin numbers	*Parameters/ sample numbers*	*pH*	*EC*	*Ca*	*Mg*	*Na*	*K*	*HCO_3*	*CO_3*	*SO_4*	*Cl*
I	BW 1	7.13	5480	992	243	112	2.0	413	00	80	1650
	” 2	6.93	3310	340	110	308	3.2	680	00	210	650
	” 3	7.23	1580	168	117	118	6.8	479	00	92	260
	” 4	7.12	1650	200	68	90	5.8	520	0.4	45	110
	” 5	7.20	1990	218	79	220	2.0	490	00	60	300
	” 6	6.80	2100	930	241	119	2.2	399	00	81	1720
	” 7	7.10	1750	360	115	315	3.0	672	00	195	682
	” 8	7.05	1840	172	128	120	6.3	460	0.2	93	277
	” 9	6.90	3120	230	72	88	5.2	498	00	48	182
	” 10	7.15	2830	228	82	217	2.4	502	0.1	65	290
II	” 11	6.72	2230	248	112	223	2.0	733	00	55	360
	” 12	7.24	850	34	09	218	3.0	296	00	103	90
	” 13	7.92	830	109	40	24	6.0	355	00	72	138
	” 14	7.94	854	55	35	110	8.0	214	00	120	90
	” 15	7.01	196	225	68	198	5.0	434	00	60	386
	” 16	6.60	2180	230	103	209	2.1	690	00	56	380
	” 17	7.12	820	72	12	215	3.0	260	0.1	106	99
	” 18	7.80	805	102	38	29	6.2	365	0.1	78	128
	” 19	7.78	880	66	42	106	7.5	205	00	103	90
	” 20	7.03	203	218	61	178	5.2	403	00	66	378
III	” 21	7.02	1689	259	131	223	4.0	351	00	38	256
	” 22	7.60	1642	245	38	180	2.0	265	00	52	300
	” 23	7.46	1036	133	32	201	6.0	245	00	46	168
	” 24	7.15	1860	205	30	290	5.8	280	0.5	72	770
	” 25	7.23	2330	185	23	305	2.0	305	00	82	400
	” 26	7.01	1602	270	128	220	4.2	345	00	35	252
	” 27	7.40	1680	240	35	189	2.5	260	0.1	54	304
	” 28	7.60	1034	128	39	205	5.0	255	0.2	42	162
	” 29	7.25	1802	200	32	280	5.8	282	00	74	772
	” 30	7.20	2225	175	28	301	2.6	302	0.5	80	402
IV	” 31	6.76	1930	160	54	301	3.2	315	00	66	278
	” 32	6.55	2041	244	86	280	5.8	397	00	37	298
	” 33	7.67	1796	128	68	272	6.2	192	00	48	300
	” 34	7.07	1850	146	78	268	9.0	461	00	62	278
	” 35	7.05	2890	140	105	255	6.2	601	00	58	500
	” 36	6.80	1860	168	58	288	3.4	306	00	62	282
	” 37	6.72	2001	242	80	290	5.5	392	0.1	36	290
	” 38	7.40	1704	132	62	301	6.0	199	00	42	305
	” 39	7.20	1860	144	70	260	8.2	468	0.2	68	272
	” 40	7.15	2790	138	99	262	6.3	572	00	54	469
V	” 41	7.02	1280	49	18	90	2.0	600	00	49	200
	” 42	6.85	900	681	305	1600	2.0	899	00	710	1550
	” 43	6.99	1630	88	22	200	2.9	720	00	75	500
	” 44	7.10	2200	62	20	218	3.2	425	0.8	78	260
	” 45	7.32	2830	52	17	305	3.9	385	0.5	66	295
	” 46	7.01	1260	52	19	92	2.2	630	00	42	205
	” 47	6.82	889	672	301	1580	2.1	850	0.1	602	1605
	” 48	6.96	1628	85	29	220	2.8	698	00	78	480
	” 49	7.09	2120	61	25	238	3.1	410	0.7	82	245
	” 50	7.28	2680	58	19	302	3.5	399	0.4	69	285

BW = Bore well
EC = Electrical conductivity (in µmho/cm)
pH in log of H^+ concentration
Ca, Mg, Na, K, HCO_3, CO_3, SO_4, Cl in ppm

Table 1d: Concentration of different chemical parameters of bore well water of sub-basin numbers I to V for the post monsoon period

Sub-basin numbers	*Parameters/ sample numbers*	*pH*	*EC*	*Ca*	*Mg*	*Na*	*K*	*HCO_3*	*CO_3*	*SO_4*	*Cl*
I	BW 1	7.33	2550	196	173	210	1.0	418	00	901	580
	” 2	7.02	2620	25	22	202	6.9	390	00	68	670
	” 3	7.14	1870	85	68	301	5.2	428	0.8	80	450
	” 4	7.60	1590	66	23	198	6.0	562	00	69	388
	” 5	7.45	2430	58	35	200	6.3	468	00	79	333
	” 6	7.35	2480	192	175	220	1.2	402	00	895	575
	” 7	7.08	2610	28	26	208	6.7	388	0.6	72	672
	” 8	7.18	1930	65	66	305	5.0	425	00	85	448
	” 9	7.65	1620	28	27	195	6.2	560	0.7	65	390
	” 10	7.50	2370	39	38	202	6.1	465	00	77	335
II	” 11	7.14	805	85	45	302	2.2	297	00	44	124
	” 12	7.43	994	101	92	368	3.0	379	00	52	124
	” 13	7.72	1648	91	34	217	3.2	459	00	68	200
	” 14	7.01	1330	240	59	268	1.2	544	00	72	260
	” 15	7.21	3280	341	163	255	3.0	398	00	88	695
	” 16	7.13	801	87	47	306	2.6	296	0.2	40	122
	” 17	7.38	988	103	94	370	3.1	380	00	48	125
	” 18	7.68	1640	93	31	219	3.3	445	00	65	190
	” 19	7.02	1302	238	57	265	1.8	540	0.2	69	252
	” 20	7.19	3262	339	161	252	3.0	385	0.1	85	640
III	” 21	7.08	1750	30	20	198	1.2	298	00	86	300
	” 22	7.11	1960	42	28	220	3.2	300	00	65	340
	” 23	7.62	2360	52	21	168	2.8	348	00	39	395
	” 24	7.48	2820	68	34	173	3.9	428	00	66	368
	” 25	7.01	2190	72	12	300	6.0	423	00	72	289
	” 26	7.06	1748	32	21	195	1.3	295	00	87	301
	” 27	7.12	1950	45	25	218	3.1	302	00	66	338
	” 28	7.58	2348	48	23	165	2.7	346	0.1	38	389
	” 29	7.45	2810	62	32	175	3.8	430	00	65	365
	” 30	7.00	2160	69	14	302	5.8	425	0.2	70	292
IV	” 31	6.71	2800	305	103	165	3.2	282	00	68	535
	” 32	6.85	1819	263	26	177	3.0	539	00	62	230
	” 33	6.06	2140	136	88	172	4.0	617	00	232	420
	” 34	6.57	3150	240	129	215	4.2	733	00	78	425
	” 35	6.31	2110	269	158	205	5.0	605	00	80	480
	” 36	6.75	2791	301	101	160	3.1	284	00	65	530
	” 37	6.80	1800	260	28	178	3.0	535	0.1	64	232
	” 38	6.12	2142	140	89	174	4.1	611	00	230	419
	” 39	6.52	3141	238	130	212	4.0	728	00	75	422
	” 40	6.28	2105	265	152	201	4.8	592	00	82	481
V	” 41	7.11	3200	35	22	168	8.4	220	0.8	33	200
	” 42	7.28	1980	68	48	185	9.2	420	00	80	268
	” 43	7.68	2820	42	30	198	6.8	368	00	68	305
	” 44	6.99	2998	39	32	221	5.0	428	00	72	315
	” 45	7.72	3230	58	42	320	6.6	326	0.9	69	275
	” 46	7.12	3180	36	23	165	8.2	215	0.6	30	201
	” 47	7.20	1960	65	45	188	9.1	418	00	82	265
	” 48	7.55	2800	43	34	195	6.2	365	00	65	306
	” 49	6.85	3001	40	33	230	5.1	421	0.5	70	312
	” 50	7.65	3210	59	44	315	6.0	322	00	73	272

BW = Bore well
EC = Electrical conductivity (in µmho/cm)
pH in log of H^+ concentration
Ca, Mg, Na, K, HCO_3, CO_3, SO_4, Cl in ppm

These specifications are based on the chemical characters of the ground water and their effects on plant growth (Table 2 [a to d]).

The ratios like Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), magnesium hazards, Kelley's ratio and chloride concentrations are considered to understand the suitability of ground water for irrigation.

Sodium Adsorption Ratio

In order to classify irrigation water the sodium concentration ratio is used. The sodium by the process of base exchange replaces calcium in the soil. It reduces the permeability of soil and has greater effect on the plant growth. The relative activity of sodium ion in the exchange reaction with soil is expressed by the SAR.

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

The SAR values in dug well water varies from 0.638 epm to 12.257 epm and for the bore well water is 0.499 epm to12.810 epm in pre monsoon period, whereas, in the post monsoon period, of dug well varies from 0.746 epm to 10.552 epm and for bore well water is 2.085 epm to 8.673 epm.

Residual Sodium Carbonate

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 decrease the soil permeability (Eaton, 1950). The indirect effect of CO_3 and HCO_3 on water quality is expressed as residual sodium carbonate (RSC).

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

The RSC value in dug well water varies from –16.238 epm to 3.401 epm whereas in bore well water it is –62.731epm to 6.169 epm in pre monsoon period. RSC values for the post monsoon period in dug well water varies from –14.160 epm to 3.589 epm. For bore well water it ranges from –23.907 epm to 5.582 epm.

Magnesium Hazards

The ratio Mg × 100/Ca + Mg is an index of magnesium

Table 2a: Irrigational specification values of dug well water samples for the pre monsoon period

Sub-basin numbers	*Parameters/sample numbers*	*SAR*	*RSC*	*Mg hazards*	*Kelley's ratio*	*SSP*
I	DW 1	12.257	2.819	38.211	5.391	84.482
	" 2	7.840	3.401	43.349	3.529	78.232
	" 3	5.416	-0.961	40.442	1.604	62.025
	" 4	11.306	2.397	40.449	4.736	82.706
	" 5	9.415	2.316	61.329	3.905	78.617
II	" 6	0.751	-0.358	33.365	3.206	21.035
	" 7	3.240	-0.135	27.258	2.845	52.095
	" 8	3.198	-0.419	30.320	2.599	50.212
	" 9	0.676	-0.589	33.851	3.043	18.921
	" 10	3.228	-0.630	27.365	2.642	51.212
III	" 11	3.221	-16.238	43.050	0.624	33.353
	" 12	4.839	-0.928	33.907	1.921	56.993
	" 13	4.603	-1.323	36.452	1.614	52.063
	" 14	3.449	-7.796	64.508	0.972	39.902
	" 15	3.763	-6.658	23.299	1.020	43.295
IV	" 16	1.119	-7.419	20.021	0.809	18.064
	" 17	0.812	-3.732	28.539	1.390	19.040
	" 18	2.454	-3.242	38.554	1.328	39.218
	" 19	0.638	-7.479	25.069	0.826	11.641
	" 20	2.409	-3.785	32.026	1.300	39.571
V	" 21	2.683	-2.423	35.955	0.166	41.839
	" 22	3.994	-1.701	27.014	0.941	52.670
	" 23	4.853	0.264	36.523	1.190	57.247
	" 24	2.715	-1.962	30.263	0.883	43.078
	" 25	4.787	-1.497	37.837	1.084	57.029

Table 2b: Irrigational specification values of dug well water samples for the post monsoon period

Sub-basin numbers	*Parameters/sample numbers*	*SAR*	*RSC*	*Mg hazards*	*Kelley's ratio*	*SSP*
I	DW 1	5.954	-1.274	33.326	1.894	65.726
	" 2	6.599	0.633	28.955	1.865	65.347
	" 3	7.439	-0.340	23.245	2.083	67.824
	" 4	5.697	-1.417	41.535	1.710	63.403
	" 5	7.847	-0.429	22.134	2.349	70.381
II	" 6	8.080	-1.115	25.252	2.427	70.932
	" 7	8.396	0.536	27.946	2.735	73.347
	" 8	10.199	3.155	52.372	3.877	79.602
	" 9	8.224	-0.900	21.972	2.539	71.849
	" 10	7.771	0.026	38.448	2.374	70.495
III	" 11	10.242	3.589	42.458	3.988	80.119
	" 12	8.509	1.322	27.946	2.772	73.636
	" 13	9.512	2.065	51.926	3.874	79.594
	" 14	10.552	2.772	45.894	4.153	80.746
	" 15	8.732	1.919	29.535	3.020	75.269
IV	" 16	9.515	3.169	43.604	3.997	80.061
	" 17	6.884	0.767	45.824	2.568	72.369
	" 18	9.421	2.044	37.072	4.468	81.833
	" 19	8.984	0.805	51.215	3.456	77.815
	" 20	8.134	1.631	52.872	3.535	78.128
V	" 21	0.746	-2.490	23.173	0.228	19.109
	" 22	2.046	-14.160	8.658	0.331	25.277
	" 23	4.384	-2.353	34.158	1.193	54.843
	" 24	3.467	-3.084	30.161	1.000	50.199
	" 25	3.919	-2.209	31.916	1.049	51.652

hazards for irrigation water (Paliwal,1972). The magnesium ratio of groundwater samples of the study, in dug well water are varying from 20.021 epm to 64.508 epm and for bore well water it varies between 17.017 epm and 55.295 epm in pre-monsoon period, whereas, for the post-monsoon period, magnesium ratio in dug well water are varying from 8.658 epm to 52.872 epm and bore well water it ranges from 14.015 epm to 62.616 epm.

Kelley's Ratio

The sodium problem in irrigational water can be worked out by the values of Kelley's ratio (Kelley et al., 1940).

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

The Kelley's ratio for dug well water varies from 0.166 epm to 5.391 epm and for bore well water it is 0.070 epm to 3.894 epm in pre monsoon period, it varies from 0.228 epm to 4.468 epm and from 0.298 epm to 2.875 epm, respectively for the post monsoon period.

The diagram for classifying irrigational water with reference to alkali and salinity hazards (U.S. Salinity Laboratory Staff, 1954). The values of electrical conductivity (EC) and SAR for all samples of the area are plotted on USSL staff diagram (Figure 5 a to d).

Wilcox (1955) 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 in dug well water varies from 11.641 epm to 84.482 epm and bore well water 6.602 epm to 79.671 epm in pre monsoon period, whereas, SSP in dug well water for the post monsoon period varies from 19.109 epm to 81.833 epm and bore well water it is 23.142 epm to 6.041 epm.

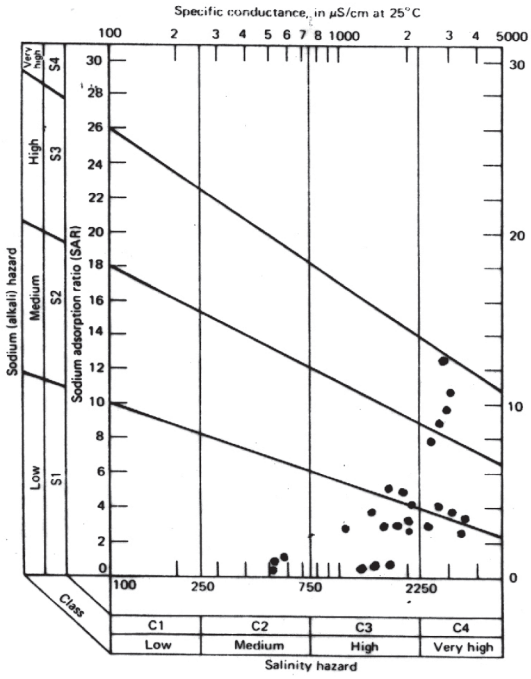
The value of EC in dug well varies from 541 to 3500 µmho/cm and bore well water it is 196 to 5480 µmho/cm in pre monsoon period, whereas, it varies from 550 to 3150 µmho/cm and 801 to 3280 µmho/cm respectively for the post monsoon period. Frequency distribution of SAR, RSC, Mg hazards, Kelley's ratio, salinity hazards and SSP is given in Table 3.

Table 2c: Irrigational specification values of bore well water samples for the pre monsoon period

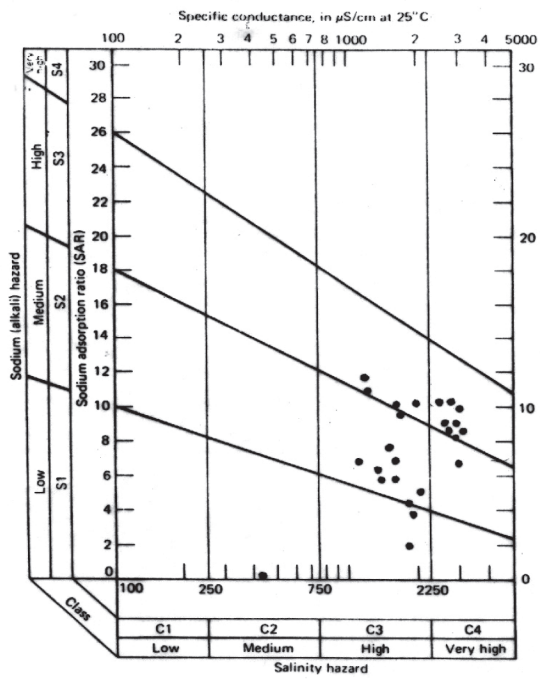
Sub-basin numbers	*Parameters/sample numbers*	*SAR*	*RSC*	*Mg hazards*	*Kelley's ratio*	*SSP*
I	BW 1	0.826	-62.731	28.776	0.070	6.602
	” 2	3.716	-14.874	34.793	0.515	34.105
	” 3	1.711	-10.161	53.458	0.285	22.642
	” 4	1.403	-7.040	35.927	0.251	20.571
	” 5	3.248	-9.349	37.410	0.550	35.612
	” 6	0.899	-59.703	29.943	0.078	7.307
	” 7	3.701	-16.415	34.507	0.499	33.419
	” 8	1.689	-11.577	55.105	0.273	21.863
	” 9	1.298	-9.240	34.047	0.220	18.438
	” 10	3.136	-9.897	37.230	0.520	34.365
II	” 11	2.954	-9.579	42.689	0.449	31.094
	” 12	8.600	2.415	30.377	3.894	79.671
	” 13	0.499	-2.913	37.704	0.119	11.781
	” 14	2.855	-2.117	51.209	0.850	46.807
	” 15	2.971	-9.710	33.263	0.512	34.130
	” 16	2.879	-8.645	42.482	0.455	31.869
	” 17	6.183	-0.318	21.554	2.043	67.281
	” 18	0.622	-2.234	38.059	0.153	14.443
	” 19	2.511	-3.389	51.207	0.683	41.379
	” 20	2.747	-9.293	31.576	0.487	33.055
III	” 21	2.819	-17.952	45.479	0.409	29.217
	” 22	2.827	-11.009	20.368	0.510	33.895
	” 23	4.064	-5.254	28.406	0.943	48.894
	” 24	5.009	-8.093	19.444	0.993	50.076
	” 25	5.628	-6.125	17.017	1.193	54.477
	” 26	2.763	-18.353	43.878	0.398	28.688
	” 27	3.017	-10.595	19.386	0.553	35.771
	” 28	4.073	-5.417	33.414	0.929	48.455
	” 29	4.852	-7.991	20.875	0.965	49.375
	” 30	5.575	-6.070	20.877	1.186	54.370
IV	” 31	5.256	-7.265	35.757	1.053	51.436
	” 32	3.927	-12.746	36.763	0.632	38.985
	” 33	4.836	-8.836	46.699	0.987	49.956
	” 34	4.456	-6.148	46.840	0.850	46.361
	” 35	3.969	-5.777	55.295	0.710	41.796
	” 36	4.887	-8.141	36.280	0.952	48.922
	” 37	4.131	-12.234	35.285	0.676	40.557
	” 38	5.419	-8.427	43.651	1.120	53.075
	” 39	4.447	-5.276	44.500	0.873	47.001
	” 40	4.159	-5.659	54.197	0.758	43.402
V	” 41	2.795	5.908	37.722	0.997	50.190
	” 42	12.810	-44.349	42.485	1.178	54.109
	” 43	4.944	5.600	29.188	1.403	58.557
	” 44	6.163	2.253	34.733	2.001	66.836
	” 45	9.399	2.333	35.036	3.323	76.977
	” 46	2.777	6.169	37.599	0.962	49.329
	” 47	12.734	-44.373	42.488	1.179	54.127
	” 48	5.259	4.813	36.004	1.444	59.236
	” 49	6.488	1.643	40.333	2.030	67.137
	” 50	8.807	2.095	35.068	2.948	74.775

Table 2d: Irrigational specification values of bore well water samples for the post monsoon period

Sub-basin numbers	*Parameters/sample numbers*	*SAR*	*RSC*	*Mg hazards*	*Kelley's ratio*	*SSP*
I	BW 1	2.637	-17.167	59.280	0.380	27.604
	” 2	7.111	3.335	59.208	2.875	74.497
	” 3	5.907	-2.796	56.887	1.331	57.304
	” 4	5.351	4.025	36.502	1.661	62.754
	” 5	5.122	1.896	49.878	1.507	60.465
	” 6	2.765	-17.394	60.055	0.399	50.044
	” 7	6.810	2.842	60.492	2.559	72.207
	” 8	6.374	-1.709	62.616	1.529	80.482
	” 9	6.308	5.582	61.398	2.344	86.041
	” 10	5.525	2.548	61.640	1.732	82.081
II	” 11	6.596	-3.076	46.322	1.654	75.662
	” 12	6.377	-6.399	60.042	1.269	76.133
	” 13	4.930	0.185	38.130	1.286	56.438
	” 14	4.021	-7.915	28.845	0.692	40.979
	” 15	2.845	-23.907	44.084	0.364	26.828
	” 16	6.575	-3.358	47.119	1.622	61.953
	” 17	6.346	-6.647	60.085	1.250	55.661
	” 18	5.026	0.102	35.474	1.325	57.165
	” 19	4.006	-7.716	28.315	0.696	41.113
	” 20	2.824	-23.857	43.925	0.363	26.768
III	” 21	6.876	1.741	52.370	2.741	73.335
	” 22	6.455	0.518	52.375	2.176	82.144
	” 23	4.972	1.381	39.981	1.691	63.025
	” 24	4.279	0.824	45.194	1.215	55.131
	” 25	8.627	2.354	21.554	2.850	74.210
	” 26	6.582	1.511	51.985	2.552	71.913
	” 27	6.470	0.648	47.814	2.205	68.940
	” 28	4.904	1.383	44.146	1.674	62.787
	” 29	4.500	1.322	45.983	1.329	57.325
	” 30	8.673	2.371	25.070	2.859	74.263
IV	” 31	2.085	-19.074	35.773	0.303	23.415
	” 32	2.788	-6.428	14.015	0.504	33.715
	” 33	2.826	-3.915	51.625	0.533	35.034
	” 34	2.783	-10.579	46.992	0.414	29.469
	” 35	2.453	-16.511	49.207	0.337	25.448
	” 36	2.038	-18.677	35.626	0.298	23.142
	” 37	2.803	-6.509	15.080	0.506	33.815
	” 38	2.831	-4.297	51.184	0.529	34.846
	” 39	2.746	-10.643	47.393	0.408	29.189
	” 40	2.438	-16.030	48.614	0.339	25.575
V	” 41	5.483	0.075	50.899	2.055	51.264
	” 42	4.201	-0.459	53.792	1.096	52.869
	” 43	5.705	1.467	54.097	1.887	65.730
	” 44	6.356	2.436	57.501	2.100	67.972
	” 45	7.818	-0.978	54.425	2.192	68.886
	” 46	5.287	-0.146	51.314	1.946	66.573
	” 47	4.391	-0.095	53.311	1.177	54.636
	” 48	5.397	1.039	56.605	1.716	63.531
	” 49	6.524	2.204	57.640	2.123	68.211
	” 50	7.568	-1.288	55.156	2.087	67.809

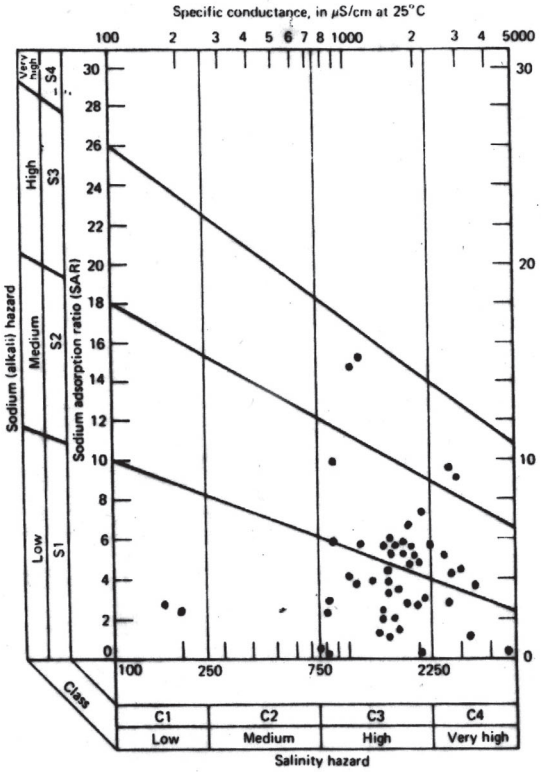


a) Pre monsoon period

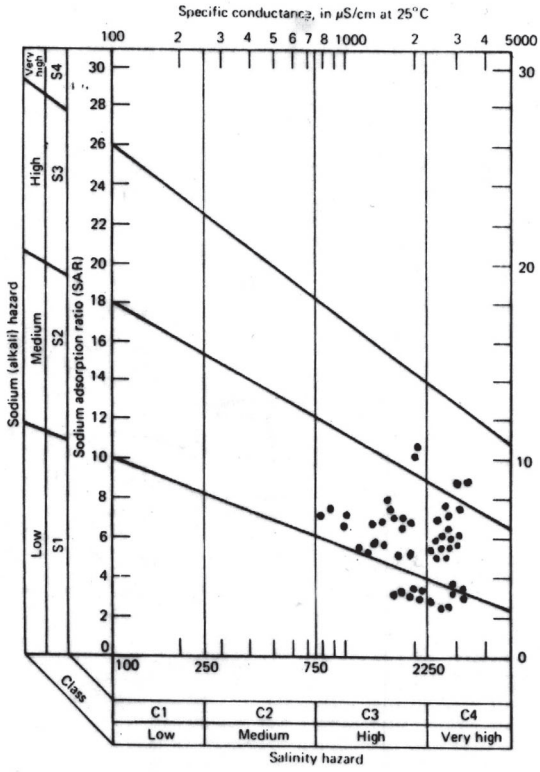


b) Post monsoon period

Figure 5 (a-b): Classification of dug well water for irrigation.



c) Pre monsoon period



d) Post monsoon period

Figure 5 (c-d): Classification of bore well water for irrigation.

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

Sr.No.	Water quality parameters	Range	Water classes	Dug wells				Bore well			
				Pre monsoon		Post monsoon		Pre monsoon		Post monsoon	
				No. of samples	%	No. of samples	%	No. of samples	%	No. of samples	%
01	U.S. Soil Salinity Diagram	$C_1 S_1$	Good	—	—	—	—	2	4	—	—
		$C_2 S_1$	Good	03	12	01	04	—	—	—	—
		$C_3 S_1$	Good	09	36	03	12	21	42	06	12
		$C_4 S_1$	Good	02	08	—	—	03	06	05	10
		$C_3 S_2$	Moderate	03	12	08	32	16	32	18	36
		$C_4 S_2$	Moderate	04	16	01	04	04	08	17	34
		$C_3 S_3$	Moderate	—	—	04	16	02	04	02	04
		$C_4 S_3$	Moderate	04	16	08	32	02	04	02	04
02	RSC	<1.25	Safe	21	84	16	64	41	82	34	68
		1.25-2.5	Marginal	02	08	05	20	05	10	11	22
		>2.5	Unsuitable	02	08	04	16	04	08	05	10
03	Mg hazards	<50%	Suitable	23	92	21	84	44	88	25	50
		50-60	Marginal	02	08	04	16	06	12	25	50
		>65	Unsuitable	—	—	—	—	—	—	—	—
04	Kelley's ratio	<1	Suitable	07	28	02	08	36	72	16	32
		1–2	Marginal	09	36	06	24	08	16	20	40
		>2	Unsuitable	09	36	17	68	06	12	14	28
05	SSP	<20	Excellent	04	16	01	04	05	10	—	—
		20-40	Good	05	20	01	04	16	32	13	26
		40-60	Permissible	11	44	03	12	23	46	12	24
		60-80	Doubtful	03	12	16	64	06	12	21	42
		>80	Unsuitable	02	08	04	16	—	—	04	08

Discussion

The quality of dug well and bore well water of the area under present investigation has been evaluated on the basis of above cited criteria (Table 3). The salinity and sodium hazards have been evaluated by using the Kelley's ratio and SAR. The Kelley's ratio is less than unity in all the dug well and bore well water samples indicate their suitable nature. All the samples are suitable for the growth of crops and rest of the samples show marginal and unsuitable for crops production. The dug well water sample numbers 11, 14, 16, 19, 21, 22 and 24 in pre monsoon period and sample numbers 21 and 22 in post monsoon period are unsuitable whereas, the bore well water sample numbers 25, 30, 31, 38, 42, 43, 47 and 48 show the marginal nature and should be restricted for sensitive crops. The sample numbers 12, 17, 44, 45, 49 and 50 are unsuitable for crops in pre monsoon period. The sample numbers 3, 4, 5, 8, 10, 11, 12, 13, 16, 17, 18, 23, 24, 28, 29, 42, 43, 46, 47 and 48 show the marginal nature and restricted to be used for sensitive crops whereas sample numbers 2, 7, 9, 21, 22, 25, 26, 27, 30, 41, 44, 45, 49 and 50 are unsuitable for crops in post monsoon period.

According to Eaton (1950) the dug well and bore well water of the study area do not have bicarbonate hazards. The dug well water sample numbers 4, 5, 12, 13, 15, 18 and 20 in pre monsoon period and sample numbers12, 13, 15, 18 and 20 in post monsoon period and bore well sample numbers 24, 44, 45, 49 and 50 in pre monsoon period and sample numbers 5, 21, 23, 25, 26, 28, 29, 30, 43, 44 and 49 in post monsoon period have RSC values between 1.25 and 2.5, indicating their marginal nature for irrigational purposes and dug well water sample numbers 1 and 2 in pre monsoon period and sample numbers 8, 11, 14 and 16 in post monsoon period and bore well sample numbers 41, 43, 46 and 48 in pre monsoon period and sample numbers 2,4, 7, 9 and 10 in post monsoon period 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 (Raghuwanshi and Thakur, 2004). The calcium ions

are liberated on 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.

Conclusion

The hydrochemical analysis data for both the seasons of groundwater samples have been presented in Table 1 [a to d]. The pH values for dug well water samples are in the range 7.05 to 7.95 during pre monsoon and 6.85 to 7.68 during post monsoon, whereas for bore well water samples are in the range of 6.55 to 7.94 during pre monsoon and 6.06 to 7.72 during post monsoon which indicate their suitable nature.

The Kelley's ratio (Table 2 [a to d]) for dug well and bore well water samples for both pre monsoon (less than unity) and post monsoon (less than unity) are suitable for the growth of crops.

The presence of carbonates, bicarbonates (Table 1 [a to d]) have indicated no hazards both for dug well and bore well water samples.

RSC values (Table 2 [a–d]) observed in between –16.238 epm and 3.401 epm in pre monsoon and 14.160 epm to 3.589 epm for dug well water samples and –62.731 epm to 6.169 epm in pre monsoon and –23.907 epm to 5.582 epm for bore well water samples indicated their marginal nature for irrigational purpose. However, more values for dug well water samples from basin number I, II, III and IV and bore well water samples from basin number I and V have indicated their unsuitable nature for the irrigational purpose of sensitive crops.

The ground water from dug well in pre monsoon and post monsoon periods is $C_3 - S_1$ to $C_4 - S_2$ and $C_3 - S_2$ to $C_4 - S_3$ respectively, which indicate high to very high salinity hazard and medium to high sodium hazard, whereas, the water from bore well in pre monsoon and post monsoon periods is $C_3 - S_1$ to $C_3 - S_2$ and $C_3 - S_2$ to $C_4 - S_2$ respectively, indicating high to very high salinity hazard and medium to high sodium hazard.

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