EVALUATION OF THE GROUNDWATER QUALITY FOR ITS SUITABILITY FOR DRINKING AND IRRIGATION IN THE INDIAN STATE OF MAHARASHTRA'S KHANAPUR TALUKA, SANGLI.

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ABSTRACT

In order to evaluate the physicochemical properties of groundwater quality in Khanapur Taluka, Sangli District, representative groundwater samples from a total of 65 bore wells and 35 dug wells were collected in the pre-monsoon and post-monsoon seasons of 2014. The physico-chemical studies of water samples from dug wells and bore wells show that alkaline earths exceed alkalies (Ca + Mg > Na + K) hydrochemical facies are present in 100% of pre- and post-monsoon samples. Similarly, 100% dug well and bore well water samples belongs to weak acid exceed strong acid (HCO$_3$ +CO$_3$ > Cl+SO$_4$) hydrochemical facies in pre and post-monsoon seasons. Out of 35 samples of water taken from dug wells in the pre-monsoon season, 12 (34.29%) and 5 (14.29%) fell into the C2 - S2 and C2 - S1 categories, respectively, indicating good water quality for irrigation. 15 samples (42.86%) belong to C3 - S2, which indicates bad water quality for irrigation, while 3 samples (8.57%) belong to C3 - S1, which indicates medium water quality for irrigation. 18 samples (51.43%) from the post-monsoon season and 4 samples (11.43%) that belong to the C2 - S2 and C2 - S1 types, respectively, indicate good water quality for irrigation. Two samples (5.71%) fit the C3-S1 type, indicating that the water is of a medium quality for irrigation. 10 samples (28.57%) are of the C3 - S2 type, indicating bad irrigation water quality, and 1 sample (2.28%) is of the C3 - S3 type, indicating very bad irrigation water quality. Similar to this, out of 65 samples of pre-monsoon bore well water, 4 samples (6.15%) and 14 samples (21.54%) respectively belong to the C2 - S1 and C2 - S2 types, indicating good water quality for irrigation. 4 samples (6.15%) fall within the C2–S3 type, which indicates irrigation water of medium quality. 38 samples (58.46%) belong to the C3 - S2 type, indicating bad irrigation water quality, while 5 samples (7.69%) belong to the C3 - S3 type, indicating very bad irrigation water quality. 15 samples (23.08%) and 10 samples (15.38%) from the post-monsoon season are of the C2 - S1 and C2 - S2 types, respectively, indicating good water quality for irrigation. 15 samples (23.88%) fall within the C3-S1 class,

which denotes irrigation water with a medium grade. 22 samples (33.85%) are of the C3 - S2 type, indicating bad irrigation water quality, while 3 samples (4.62%) are of the C3 - S3 type, indicating very bad irrigation water quality. According to the Gibbs variation diagram, rock dominance is what regulates the chemistry of groundwater.

Keywords: Groundwater quality, Khanapur Taluka, Hydro-chemical facies.

INTRODUCTION

Saline water bodies make up the ocean, which contains 97% of the world's water. Only 1% of the remaining 2% of fresh water is usable for drinking and irrigation, with the rest being trapped in icecaps and glaciers. In Khanapur Taluka, groundwater is the primary and most significant source for agricultural and drinking water. Because of the inconsistency and low rainfall in the research area, there is still a water shortage concern. Farmers adopt contemporary agricultural techniques to increase productivity while using scarce water resources, and as a result, the research area's groundwater quality is expected to suffer as a result. People from both rural and urban areas should be aware of the chemical properties of groundwater needed for drinking, domestic use, and agriculture.

A trilinear diagram was created by Piper (1953) to characterise the hydrochemical facies. Several aspects of groundwater chemistry were explored by Todd (1959) and Karanth (1987). The chemical makeup of groundwater from metropolitan areas has been studied by Tiwari (1988), Pawar (1993), Shenoy and Lokesh (1999), Sawant and Joshi (1999), Ahmed et al. (2002), Panaskar et al. (2007), Yadav et al. (2011), Yadav and Sawant (2012), and Yadav and Sawant (2014). The writers of this work have concentrated on the chemistry, quality, and usability of groundwater for irrigation and drinking.

STUDY AREA

The research region is located between latitudes 17° 13' 33" and 17° 61' 38" N and longitudes 74° 41' 45" and 74° 90' 12" E and is included in Survey of India Toposheet numbers 47 K/7, 47 K/8, 47 K/11, 47 K/12, 47 K/15, and 47 K/16 on a scale of 1:50000 (Fig. 1). The Deccan trap, which dates from the Upper Cretaceous to the Lower Eocene, covers the area. The production of grapes and pomegranates is widely recognized in the research region. Bore wells and dug wells are the primary sources of water for drinking, irrigation, and industrial uses.
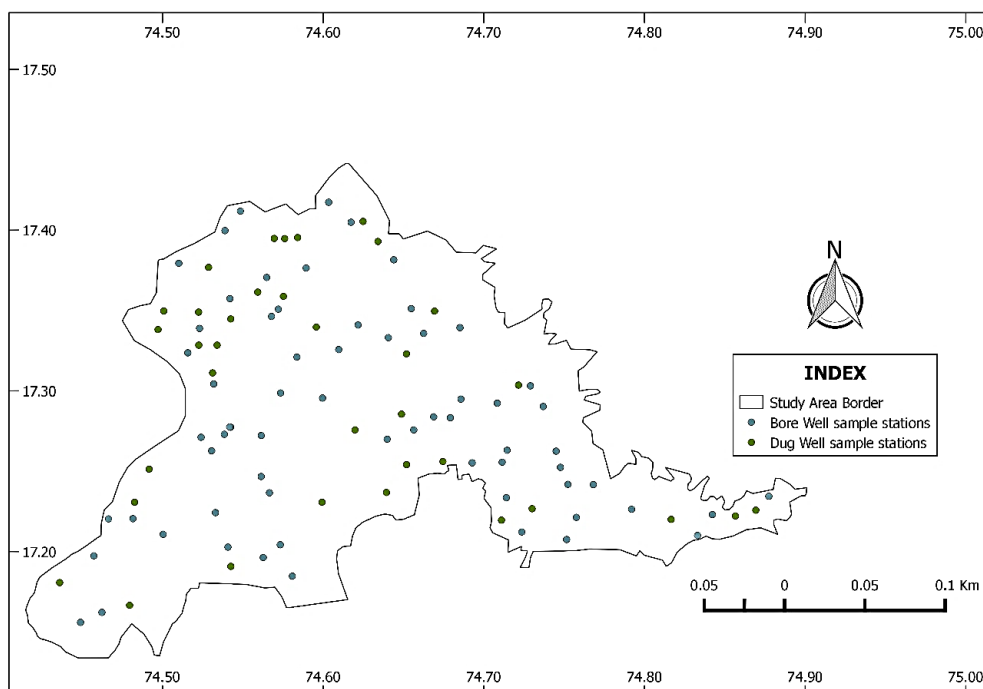
Fig.1: Map showing sampling locations of dug well and bore well water samples of Khanapur Taluka.

METHODOLOGY

100 representative groundwater sampling locations were chosen to fulfil the study's goal. For the purpose of evaluating the quality of groundwater, a total of 35 dug well and 65 bore well water samples were collected in the 2014 pre- and post-monsoon seasons (Fig. 1). Plastic bottles of one liter size were used to collect the samples. To prevent water contamination, precautions were taken before collecting samples. After washing them before collection, separate bottles were utilized for each station. The labels on the collected water samples were correct. At the time of sample collection, the various physical parameters, including colour, aroma, taste, turbidity, and foam, were determined. The various chemical parameters were examined using the protocols established by Trivedy and Goel (1986); APHA, AWWA, and WPCF (1992).

RESULTS AND DISCUSSION

Chemical Analysis of Groundwater Samples

To examine various parameters, chemistry was used. It includes the amount of bicarbonate (HCO_3), carbonate (CO_3), and Sulphate (SO_4) present in the groundwater, as well as the concentration of hydrogen ions (pH), electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), and total alkalinity (TA). For groundwater samples taken in the pre-monsoon and post-monsoon seasons of 2014, the chemical analysis, Maximum, Minimum, Average, and Standard Deviation of all chemical constituents are obtained are reported in Table 1a to d. The outcomes were compared to Indian and World Health Organization (WHO) standards.

Table 1.a: Data showing Chemical analysis, Maximum, Minimum, Average and Standard deviation values of Dug well water samples of study area (Pre - monsoon season, 2014).

Dugwell No.	pH	EC μs/cm	TA	TH	TDS	Ca	Mg	Na	K	HCO₃	CO₃	SO₄	CL
DW-1	7.84	1284	6.2	56	834.6	165	21	37	14	337	0.5	87	15.3
DW-2	7.61	1423	7.2	41	924.95	95	24	64	20	578	2.9	76	20.4
DW-3	7.98	1135	5.3	38	737.75	112	37	84	25	485	1.7	94	14.9
DW-4	8.12	1287	4.1	51	836.55	135	31	56	28	398	0.3	84	26.1
DW-5	7.45	1245	5.7	32	809.25	87	26	47	18	678	3.2	37	20.7
DW-6	7.84	1291	8.1	41	839.15	96	17	36	23	325	2.7	48	11.3
DW-7	7.61	1325	6.8	26	861.25	145	39	83	24	475	1.4	20	23.4
DW-8	7.86	1511	7.1	46	982.15	156	27	94	29	658	3.6	95	51.3
DW-9	8.01	982	8.1	20	638.3	135	25	67	21	687	3.4	47	7.2
DW-10	7.58	697	5.2	35	453.05	96	14	34	27	312	0.4	30	8.1
DW-11	7.98	1123	4.8	47	729.95	89	26	49	16	486	0.8	94	10.2
DW-12	7.45	986	8.1	36	640.9	137	27	61	19	624	1.2	91	9.4
DW-13	8.12	546	4.2	24	354.9	98	19	53	24	502	3.2	83	14.3
DW-14	7.36	628	6.2	40	408.2	86	17	48	27	412	0.5	96	6.1
DW-15	8.45	912	7.8	34	592.8	197	34	51	29	491	1.5	84	5.3
DW-16	8.12	1023	6	47	664.95	186	38	94	29	368	0.6	62	13.5
DW-17	7.65	981	7.3	38	637.65	165	31	83	26	547	1.3	71	4.1
DW-18	7.98	861	6.8	32	559.65	139	27	64	17	413	1.4	62	8.1
DW-19	8.23	1154	7.1	41	750.1	103	20	41	26	698	3.4	87	9.2
DW-20	7.54	846	6.2	39	549.9	97	18	53	19	627	3.2	98	16.2
DW-21	8.23	1365	5.2	48	887.25	86	16	37	14	368	0.6	57	24.3
DW-22	7.4	1248	6.3	53	811.2	168	27	68	29	673	1.9	96	11.3
DW-23	8.35	689	2.6	4.6	447.85	96	24	84	24	587	3.2	81	24.3
DW-24	7.84	1547	6.9	41	1005.6	145	37	91	23	415	2.6	63	41.2
DW-25	7.56	856	7.6	38	556.4	95	29	47	19	391	0.7	57	10.1
DW-26	8.03	1135	7.9	47	737.75	86	21	68	20	624	3.1	97	49.2
DW-27	7.69	1032	5.2	34	670.8	198	29	99	27	419	2.4	59	20.3
DW-28	8.25	974	6.2	51	633.1	165	38	73	29	371	0.5	48	10.8
DW-29	8.12	1289	5.7	21	837.85	124	19	82	27	564	2.8	86	9.3
DW-30	7.68	947	7.3	44	615.55	106	26	67	21	659	3.1	98	46.2
DW-31	7.67	1068	4.9	26	694.2	147	37	63	17	620	2.7	93	31.8
DW-32	8.07	963	6.3	38	625.95	186	38	95	26	394	0.4	41	16.2
DW-33	8.45	1149	7.9	42	746.85	176	36	96	27	587	1.6	79	9.7
DW-34	7.35	1397	6.8	28	908.05	154	26	72	24	681	3.4	93	18.2
DW-35	8.27	1278	7.6	46	830.7	183	34	70	26	679	3.1	99	6.2

Dugwell No.	pH	EC μs/cm	TA	TH	TDS	Ca	Mg	Na	K	HCO₃	CO₃	SO₄	CL
Standard deviation	0.322	248	1.31	10.7	161.208	36.95	7.41	19	4.57	125.55	1.15	22.3	12.56
Average	7.88	1091	6.36	37.9	709.00	132.4	27.3	66	23.3	518.09	1.98	74.1	17.83
Maximum	8.45	1547	8.1	56.2	1005.55	198	39	99	29	698	3.6	99	51.3
Minimum	7.35	546	2.6	4.6	354.9	86	14	34	14	312	0.3	20	4.1

DW = Dug well All values are expressed in mg/l except pH. The EC values are in μs/cm.

Table 1.b: Data showing Chemical analysis, Maximum, Minimum, Average and Standard deviation values of Dug well water samples of study area (Post - monsoon season, 2014).

Dugwell No.	pH	EC μs/cm	TA	TH	TDS	Ca	Mg	Na	K	HCO₃	CO₃	SO₄	CL
DW-1	7.78	1183	5.7	43.5	768.95	133	16	26	11	267	0.3	94	12.9
DW-2	7.14	1324	6.8	23.6	860.6	89	25	47	22	435	2.7	56	16.8
DW-3	7.31	1222	5.3	35.5	794.3	94	22	58	18	356	1.5	89	15.2
DW-4	7.87	1171	3.7	41.5	761.15	98	26	39	21	216	0.1	76	21.5
DW-5	7.69	1097	6.2	23.8	713.05	74	17	27	14	547	3	23	16.8
DW-6	7.59	1133	6	35	736.45	87	14	24	17	278	2.5	42	9.7
DW-7	7.2	1326	7	28.8	861.9	123	35	94	29	364	1.2	16	18.3
DW-8	7.56	1450	5	44.3	942.5	111	21	76	24	697	3.4	84	41.9
DW-9	7.81	875	5.9	17.8	566.8	102	18	43	19	546	3.2	36	6.5
DW-10	7.9	653	3.7	21	424.45	86	16	29	17	263	0.2	27	6.7
DW-11	7.87	1032	5	36.4	670.8	79	19	38	14	365	0.6	98	7.2
DW-12	7.39	844	5.3	29.5	548.6	96	20	41	17	456	1	85	7.5
DW-13	7.71	537	3.5	17.2	349.05	83	16	47	16	489	3	79	11.7
DW-14	7.24	589	4.7	21	382.85	79	12	32	26	268	0.3	91	4.1
DW-15	8.14	803	6.4	29.7	521.95	180	29	36	20	367	1.4	74	3.6
DW-16	8.16	884	5	30.5	574.6	165	34	79	27	289	0.5	59	9.4
DW-17	7.95	788	5.9	24.5	512.2	125	22	83	29	467	1.2	67	3.9
DW-18	7.48	868	5.7	22.3	564.2	107	19	42	13	359	1.3	51	6.9
DW-19	7.94	960	6.5	26.2	624	97	15	37	19	543	3.3	97	6.6
DW-20	7.13	675	5.5	23.5	438.75	89	10	31	14	649	3.1	93	9.5
DW-21	8.01	1242	5.8	37.2	807.3	77	10	29	13	264	0.5	48	16.4
DW-22	7.76	1006	6.9	36.1	653.9	136	19	57	25	539	1.8	81	8.2
DW-23	8.05	585	1.6	3.8	380.25	86	17	64	28	479	2.9	76	14.2
DW-24	7.38	1481	5.4	33.2	962.65	95	20	73	21	319	2.3	51	34.2
DW-25	7.26	735	7.3	23.2	477.75	84	14	38	18	267	0.4	43	9.7
DW-26	7.91	1051	6.4	34.8	683.15	78	19	41	16	546	2.8	96	37.9
DW-27	7.38	913	4.8	22.7	593.45	157	37	97	27	394	2.1	49	15.7
DW-28	8.03	875	5.9	31.1	568.75	135	24	73	26	268	0.2	35	9.2
DW-29	7.57	1103	4.6	16.4	716.95	109	21	67	21	496	2.5	72	6.2
DW-30	7.91	847	6.1	32.7	550.55	97	16	45	17	685	2.8	94	32.8
DW-31	7.23	934	3.2	18.3	607.1	113	22	58	12	531	2.4	81	22.4
DW-32	7.86	810	5.2	26.9	526.5	157	34	91	23	296	0.1	37	13.7

Dugwell No.	pH	EC µs/cm	TA	TH	TDS	Ca	Mg	Na	K	HCO₃	CO₃	SO₄	CL
DW-33	8.13	1047	6.8	38.6	680.55	143	30	84	26	476	1.3	69	7.9
DW-34	7.64	1245	7.1	19.7	809.25	127	27	61	20	635	3.1	87	11.7
DW-35	8.07	1169	5.9	39.7	759.85	174	39	68	29	689	2.8	91	5.4
Standard deviation	0.32	244.6	1.23	8.972	159.026	30	7.56	22	5.41	142.22	1.14	24.2	9.718
Average	7.69	984.5	5.48	28.29	639.86	110	21.6	54	20.3	431.57	1.77	67.1	13.78
Maximum	8.16	1481	7.3	44.3	962.65	180	39	97	29	697	3.4	98	41.9
Minimum	7.13	537	1.6	3.8	349.05	74	10	24	11	216	0.1	16	3.6

DW = Dug well   All values are expressed in mg/l except pH. The EC values are in µs/cm.

Table 1.c: Data showing Chemical analysis, Maximum, Minimum, Average and Standard deviation values of Bore well water samples of study area (Pre-monsoon season, 2014).

Borewell no.	pH	EC	TA	TH	TDS	Ca	Mg	Na	K	HCO₃	CO₃	SO₄	CL
BW-1	9.12	590	3.9	48.08	383.5	65	28	94	8	875	9.4	87	12.3
BW-2	7.89	1380	7.6	61.5	897	94	21	38	16	298	0.96	64	32.4
BW-3	7.2	1252	8.9	47	813.8	165	39	86	29	364	0.24	52	21.8
BW-4	8.1	1380	8.6	76	897	79	27	54	17	501	2.6	89	35.2
BW-5	7.5	1320	6.4	46.2	858	142	25	79	16	324	0.42	64	24.1
BW-6	8.24	1475	8.2	60.5	958.75	136	14	35	17	514	3.72	83	41.3
BW-7	7.63	1275	7.3	45.3	828.75	187	17	84	24	625	1.11	49	15.1
BW-8	7.2	1412	9.2	41.3	917.8	94	16	92	16	578	0.38	56	19.2
BW-9	8.12	1371	5.6	56.2	891.15	186	34	97	17	358	1.96	76	46.2
BW-10	7.35	1275	7.2	61.3	828.75	94	16	65	26	245	0.22	59	47.3
BW-11	7.89	1463	5.9	48.2	950.95	87	18	26	21	324	1.04	76	59.1
BW-12	8.23	954	7.2	39	620.1	135	16	76	18	415	2.93	62	10.2
BW-13	8.15	712	6.2	26.4	462.8	145	28	97	34	567	3.33	46	7.2
BW-14	7.86	1287	8.1	32.1	836.55	204	37	82	21	526	1.58	69	31.5
BW-15	7.65	814	6.3	28.3	529.1	187	29	79	16	421	0.78	42	11.2
BW-16	7.65	1490	8.4	41.8	968.5	132	36	71	29	384	0.71	91	51.9
BW-17	7.91	1356	5.9	51.2	881.4	89	27	45	21	698	2.36	89	20.4
BW-18	9.26	647	3.5	43.08	420.55	176	46	32	32	568	7.3	98	10.6
BW-19	8.24	1152	8.2	34.1	748.8	149	24	46	14	529	3.83	63	9.3
BW-20	7.56	850	6.1	20.1	552.5	189	39	78	19	457	0.69	74	7.7
BW-21	7.65	1136	7.3	9.4	738.4	176	23	47	20	713	1.32	92	36.4
BW-22	8.24	892	6.8	36.2	579.8	92	21	98	26	315	2.28	99	12.8
BW-23	7.82	1234	8.2	31.7	802.1	114	18	96	37	384	1.05	49	20.9
BW-24	7.63	1304	6.9	56.4	847.6	165	26	85	18	425	0.75	94	36.7
BW-25	8.29	1354	7.3	49.2	880.1	186	26	76	31	678	5.51	35	40.2
BW-26	7.91	1369	5.2	40.3	889.85	145	27	52	17	624	2.11	46	25.3
BW-27	8.31	1184	8.3	38.4	769.6	128	19	43	15	458	3.89	68	9.1
BW-28	7.54	1206	8.9	16.4	783.9	97	20	97	24	695	1	51	6.2
BW-29	8.02	1483	7.6	49.8	963.95	82	15	99	18	489	2.13	82	51.3
BW-30	7.68	1357	6.8	36.1	882.05	199	49	87	20	524	1.04	94	40.6
BW-31	8.87	964	5.4	21.29	626.6	164	34	83	17	689	9.2	73	20.9

Borewell no.	pH	EC	TA	TH	TDS	Ca	Mg	Na	K	HCO₃	CO₃	SO₄	CL
BW-32	7.86	685	4.9	11.3	445.25	192	41	41	25	352	1.06	68	14.8
BW-33	7.91	1102	6.7	51.2	716.3	116	27	84	16	475	1.6	51	16.1
BW-34	8.35	703	5.1	14.3	456.95	254	15	85	27	614	5.73	49	20.5
BW-35	7.65	1238	9.1	18.7	804.7	165	14	65	26	365	0.67	83	14.8
BW-36	7.61	1034	7.4	39.1	672.1	187	27	43	20	702	1.19	82	11.9
BW-37	8.03	1536	9.2	26.7	998.4	166	26	87	19	658	2.93	48	46.5
BW-38	7.52	1307	5.9	49.3	849.55	211	27	82	23	578	0.79	71	24.8
BW-39	7.68	1205	7.8	36.7	783.25	198	16	79	17	675	1.34	89	8.1
BW-40	7.93	1287	8.1	25.9	836.55	167	32	94	16	412	1.46	93	25.3
BW-41	7.69	1415	9.8	52.3	919.75	178	18	78	16	652	1.33	87	40.6
BW-42	7.38	1297	8.7	39.5	843.05	96	26	36	24	486	0.48	69	29.1
BW-43	7.91	746	8.6	38.4	484.9	79	29	87	26	624	2.11	48	25.7
BW-44	7.59	1254	8.2	36.7	815.1	112	16	51	18	314	0.5	83	26.5
BW-45	8.05	1032	9.7	18.3	670.8	97	27	96	20	721	3.37	97	9.2
BW-46	7.39	978	8.4	53.2	635.7	135	26	92	29	465	0.47	52	27.9
BW-47	8.24	935	9.4	37.2	607.75	91	35	61	24	314	2.27	93	10.4
BW-48	8.26	1297	5.2	14.5	843.05	145	38	78	34	426	3.23	84	19.3
BW-49	7.86	967	6.9	56.3	628.55	198	41	36	17	654	1.97	67	26.7
BW-50	7.87	1065	9.2	18.5	692.25	187	28	74	21	578	1.78	91	56.2
BW-51	8.04	985	8.3	37.6	640.25	196	37	91	19	698	3.19	87	48.3
BW-52	7.37	1198	5.2	39	778.7	106	18	73	29	368	0.35	45	59.1
BW-53	7.84	1209	7.6	57.1	785.85	98	29	81	16	732	2.11	83	26.8
BW-54	8.09	1520	9.8	36.2	988	115	24	42	23	524	2.68	91	21.3
BW-55	8.28	687	6.4	24.3	446.55	97	16	25	30	423	3.36	65	34.2
BW-56	7.69	864	9.1	18.6	561.6	135	23	56	17	689	1.4	62	27.6
BW-57	7.93	1136	8.6	36.9	738.4	178	34	47	16	547	1.94	97	40.3
BW-58	7.68	897	9.1	46.8	583.05	168	38	84	24	614	1.22	68	37.2
BW-59	7.87	961	8.5	37.1	624.65	124	29	36	19	326	1	49	20.9
BW-60	7.53	1268	8.1	26.4	824.2	93	24	49	20	654	0.92	87	41.3
BW-61	7.43	1523	6.7	40.5	989.95	109	21	57	27	597	0.66	79	27.1
BW-62	7.91	1305	5.3	45.2	848.25	94	16	76	16	365	1.23	93	9.1
BW-63	7.83	1292	6.4	60.1	839.8	118	28	65	28	568	1.6	78	48.2
BW-64	7.84	954	9.6	52.9	620.1	126	34	48	16	687	1.98	96	10.5
BW-65	7.79	1169	9.7	46.3	759.85	189	39	97	23	357	1.68	84	14.2
Standard deviation	0.39	247	1.5	14.289	160.616	43	8.5	22	5.8	143.13	1.88	17.7	14.6
Average	7.89	1154	7.4	39.01	749.89	142	27	69	21	519.68	2.08	72.9	26.7
Maximum	9.26	1536	9.8	76	998.4	254	49	99	37	875	9.4	99	59.1
Minimum	7.2	590	3.5	9.4	383.5	65	14	25	8	245	0.22	35	6.2

DW = Dug well   All values are expressed in mg/l except pH. The EC values are in μs/cm.

Table 1.d: Data showing Chemical analysis, Maximum, Minimum, Average and Standard deviation values of Bore well water samples of study area (Post-monsoon season, 2014).

Borewell no.	pH	EC	TA	TH	TDS	Ca	Mg	Na	K	HCO₃	CO₃	SO₄	CL
BW-1	10.11	558	1.2	54	362.7	86	26	99	9	876	2.5	98	10.4
BW-2	7.69	1369	6.4	49.4	889.85	97	16	34	15	264	0.4	53	24.3

Borewell no.	pH	EC	TA	TH	TDS	Ca	Mg	Na	K	HCO$_3$	CO$_3$	SO$_4$	CL
BW-3	7.17	1252	7.5	32	813.8	126	34	96	24	359	1.2	46	14.1
BW-4	7.83	1343	8.4	62.7	872.95	68	27	45	12	461	3.1	75	45.5
BW-5	7.3	1257	5.5	36.5	817.05	79	19	68	13	227	0.5	68	20.5
BW-6	7.32	1475	7.7	60.5	958.75	126	16	28	17	446	2.5	67	33.5
BW-7	7.66	1257	6.7	40.6	817.05	163	18	67	19	568	3.4	53	10.5
BW-8	6.7	1332	9.1	36.7	865.8	86	13	98	15	471	2.4	39	12.9
BW-9	7.29	1412	4.9	40.6	917.8	165	29	83	11	268	0.6	87	30.2
BW-10	7.09	1371	6.7	42.2	891.15	76	13	45	19	245	0.4	49	52.2
BW-11	7.64	1388	3.8	34.7	902.2	83	14	23	16	239	0.4	68	47.7
BW-12	7.53	875	5.2	34	568.75	98	11	67	13	315	2.3	58	8.5
BW-13	7.5	648	4.3	22.8	421.2	112	19	83	28	567	3.1	43	4.4
BW-14	8.15	1235	5	20.8	802.75	197	24	69	26	496	2.3	62	18.5
BW-15	7.36	919	5.6	23.9	597.35	147	29	74	14	315	2.1	39	8.4
BW-16	7.12	1514	7.5	35.2	984.1	91	26	65	29	297	0.5	87	39.2
BW-17	7.2	1306	5.9	36	848.9	78	19	34	16	698	3.2	86	14.6
BW-18	8.47	539	1.4	42	350.35	146	38	29	27	475	1.8	94	10.6
BW-19	7.44	1097	8.2	25	713.05	135	24	39	16	526	2.3	51	8.4
BW-20	7.29	850	4.2	15.2	552.5	171	34	64	17	348	1.5	62	6.7
BW-21	7.61	1136	5.6	83	738.4	126	19	39	13	685	3.1	86	22.7
BW-22	7.85	892	5.3	31.2	579.8	89	14	87	24	254	0.8	91	9.7
BW-23	7.9	1080	6.9	26.8	702	98	12	91	26	278	0.4	36	11.7
BW-24	7.22	1295	5.6	44.5	841.75	124	11	80	15	364	1.5	94	20.9
BW-25	7.74	1224	4.7	38.8	795.6	134	16	63	27	568	2.6	25	18.2
BW-26	7.54	1241	4.7	39.7	806.65	106	18	41	15	657	3.2	36	22.4
BW-27	7.7	1184	7.2	33.3	769.6	97	14	38	17	423	2.6	54	8.7
BW-28	7.65	1121	9.3	14.7	728.65	89	18	69	22	695	3.1	48	4.5
BW-29	7.47	1475	7.4	37.5	958.75	76	12	94	14	326	1.6	76	32.8
BW-30	7.49	1332	4.8	38	865.8	167	37	96	17	457	3.4	81	28.2
BW-31	8.7	913	3.2	42	593.45	124	26	91	16	624	3.2	61	12.7
BW-32	7.47	677	3.2	21	440.05	164	31	29	28	267	0.3	58	10.2
BW-33	7.83	1078	4.5	37	700.7	93	15	68	13	335	1.3	49	11.6
BW-34	8.26	604	4.5	10.5	392.6	216	17	74	22	524	3.6	38	10.9
BW-35	7.4	1063	8.5	18.7	690.95	179	13	42	18	228	0.5	79	10.4
BW-36	7.16	976	7.2	35	634.4	156	19	35	19	644	3.2	61	8
BW-37	7.82	1511	8	21.2	982.15	147	24	59	16	524	3.8	38	46.5
BW-38	7.18	1281	5.9	44.5	832.65	191	35	97	17	463	2.3	69	15.4
BW-39	7.79	1186	7.6	30.5	770.9	165	21	78	14	668	3.5	73	6.5
BW-40	7.93	1217	7.1	28.5	791.05	146	20	81	12	245	0.5	84	14.2
BW-41	7.35	1415	9.8	39.6	919.75	135	20	62	11	456	2.8	92	23
BW-42	7.52	1207	8.7	37.1	784.55	89	17	24	13	335	1.6	54	13.4
BW-43	7.35	684	8.1	23.7	444.6	75	16	63	18	468	3.1	37	14.5
BW-44	7.1	1016	7.5	31	660.4	86	11	39	20	298	0.5	64	26.5
BW-45	7.89	985	9.7	12.6	640.25	87	16	87	16	679	3.4	82	6.8
BW-46	7.25	756	7.6	39.2	491.4	93	19	86	21	468	2.5	46	16.7
BW-47	7.95	894	8	20	581.1	78	27	45	17	277	0.4	81	8.9
BW-48	8.12	1156	4.8	16.8	751.4	119	21	59	28	365	0.4	76	10.7
BW-49	7.46	1052	5.4	40.1	683.8	168	34	24	16	654	3.6	54	15.9

Borewell no.	pH	EC	TA	TH	TDS	Ca	Mg	Na	K	HCO₃	CO₃	SO₄	CL
BW-50	7.58	957	8.4	18.5	622.05	143	14	53	17	452	2.1	86	40.7
BW-51	7.83	856	7.8	26.7	556.4	175	39	68	12	678	2.9	64	34.2
BW-52	7.26	1035	4.9	10.4	672.75	96	14	74	26	258	0.6	39	49.4
BW-53	7.54	1125	6.7	36.4	731.25	83	19	94	14	697	3.2	79	10.6
BW-54	7.91	1520	9.4	27.3	988	81	12	29	21	357	1.4	82	17.6
BW-55	7.81	598	4.7	18	388.7	79	18	27	29	346	2.6	67	19.4
BW-56	7.21	783	7.9	14.6	508.95	91	16	48	14	528	3.2	49	11.6
BW-57	7.63	946	7.6	28.2	614.9	126	20	37	18	369	1.8	86	24
BW-58	7.97	852	7.8	31.8	553.8	138	31	59	17	428	2.8	57	20.4
BW-59	7.58	869	7.8	21.7	564.85	96	14	24	13	257	0.6	37	12.6
BW-60	7.16	1135	7.3	16.5	737.75	78	19	41	12	654	3.2	64	27.4
BW-61	7.99	1420	4.7	29.4	923	94	16	36	27	587	3.5	52	16.4
BW-62	7.58	1286	4.9	36.1	835.9	86	13	58	13	243	0.8	81	7.3
BW-63	7.41	1152	6.7	46.9	748.8	83	17	41	25	664	2.6	64	26.1
BW-64	7.69	987	9.2	35.2	641.55	98	26	39	12	543	3.1	91	8.1
BW-65	7.53	1045	8.4	47.2	679.25	167	32	76	17	298	0.27	87	7.6
Standard deviation	0.471	257.4	1.93	13.15	167.32	37	7.54	23.3	5.4	160.98	1.148	18.72	12.0736
Average	7.62	1096	6.46	32.71	712.14	118	20.6	59.3	18	446.91	2.06	64.51	18.72
Maximum	10.11	1520	9.8	83	988	216	39	99	29	876	3.8	98	52.2
Minimum	6.7	539	1.2	10.4	350.35	68	11	23	9	227	0.27	25	4.4

DW = Dug well   All values are expressed in mg/l except pH. The EC values are in μs/cm.

The spatial distribution of all chemical parameters (Figs. 2.1 to 2.13), show a change between the pre- and post-monsoon seasons of 2014. In the post-monsoon season, pH values between 6.70 and 8 increased and those between 8 and 9.25 declined, according to Fig. 2.1. In the post-monsoon season, electrical conductivity (EC) marginally decreased (Fig. 2.2). During the post-monsoon season, the concentrations of total alkalinity (TA) and total hardness (TH) were noticeably lower (Figs. 2.3 and 2.4). In the post-monsoon season, the concentrations of calcium (Ca), magnesium (Mg), and total dissolved solids (TDS) all marginally reduced (Figs. 2.5, 2.6, and 2.7). During the post-monsoon season, the concentrations of sodium (Na), potassium (K), bicarbonate (HCO3), sulphate (SO4), and chloride (Cl) declined (Figs. 2.8, 2.9, 2.10, 2.12, and 2.13). While carbonate (CO3) content rose in the post-monsoon season (Fig. 2.11). Except for Carbonate (CO3), all chemical parameter concentrations fell during the post-monsoon season compared to the pre-monsoon season.
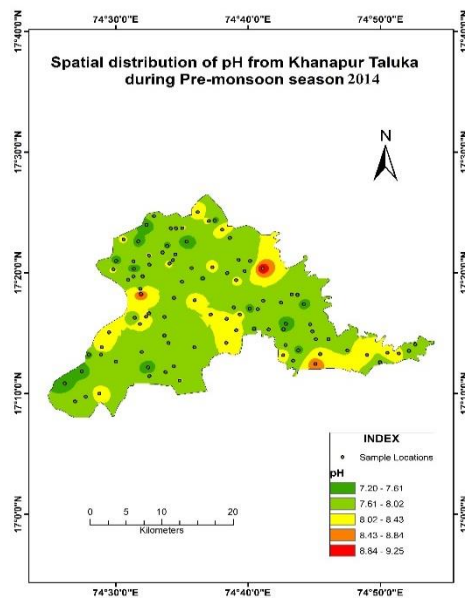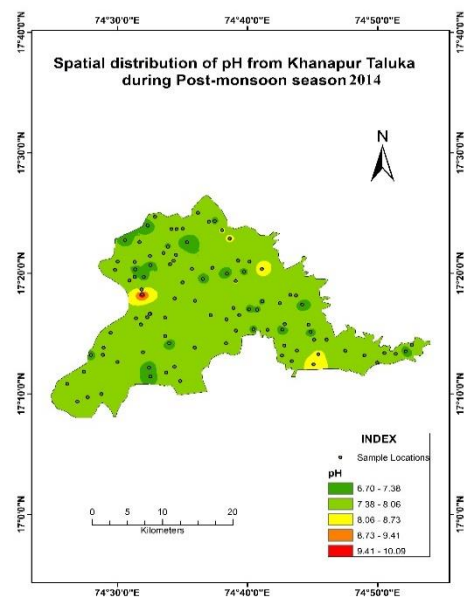
(a)   (b)
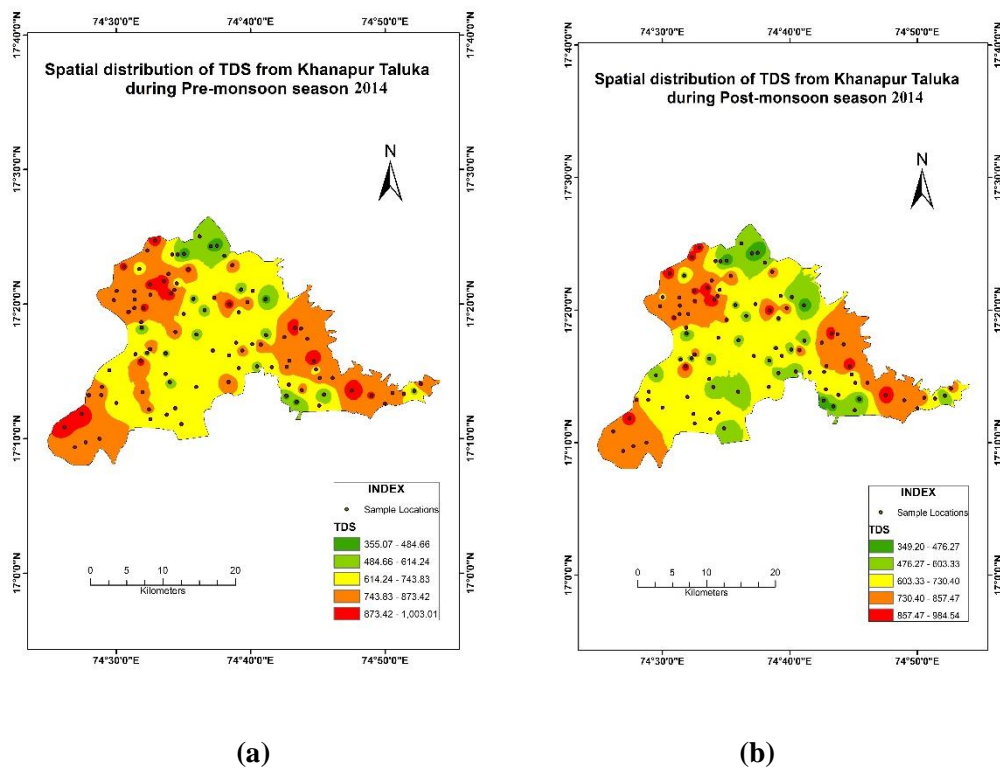
Fig. 2.1 Spatial distribution of pH during Pre and Post monsoon season 2014.
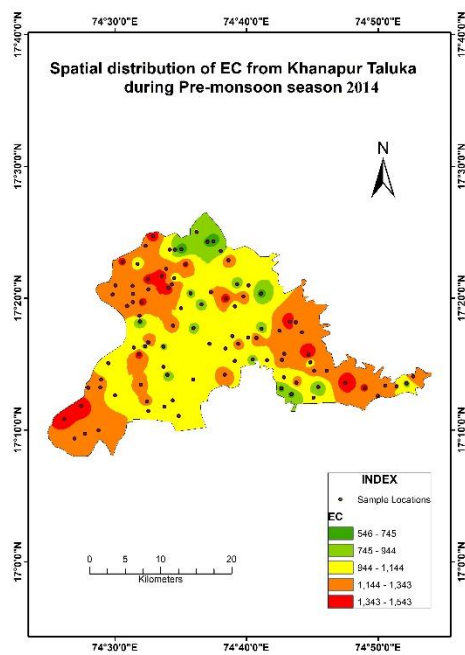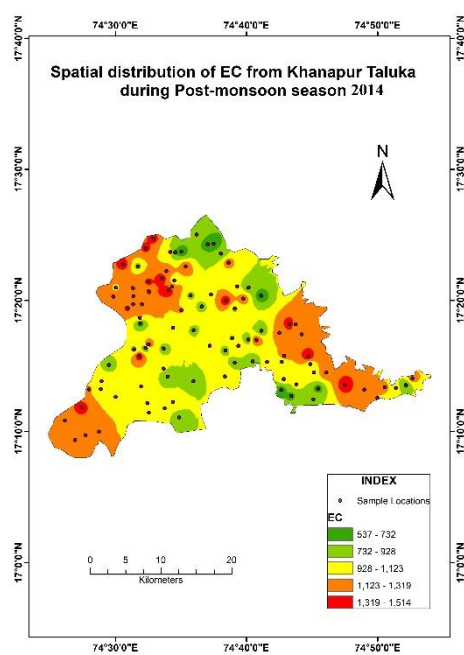
(a)   (b)

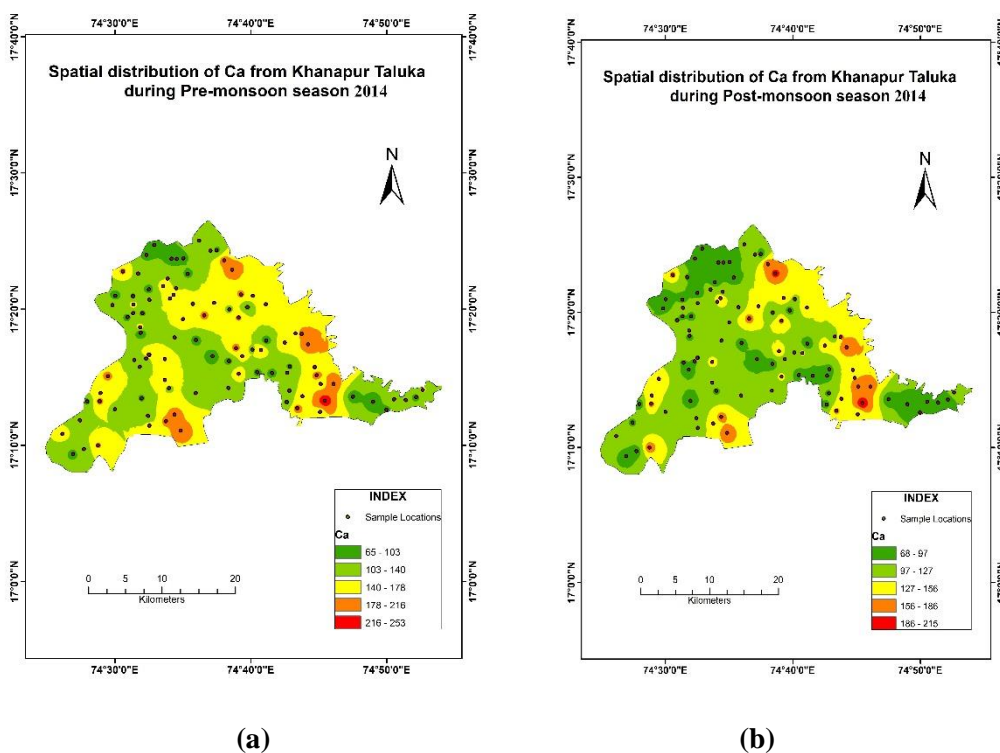**Fig. 2.2 Spatial distribution of EC during Pre and Post monsoon season 2014.**
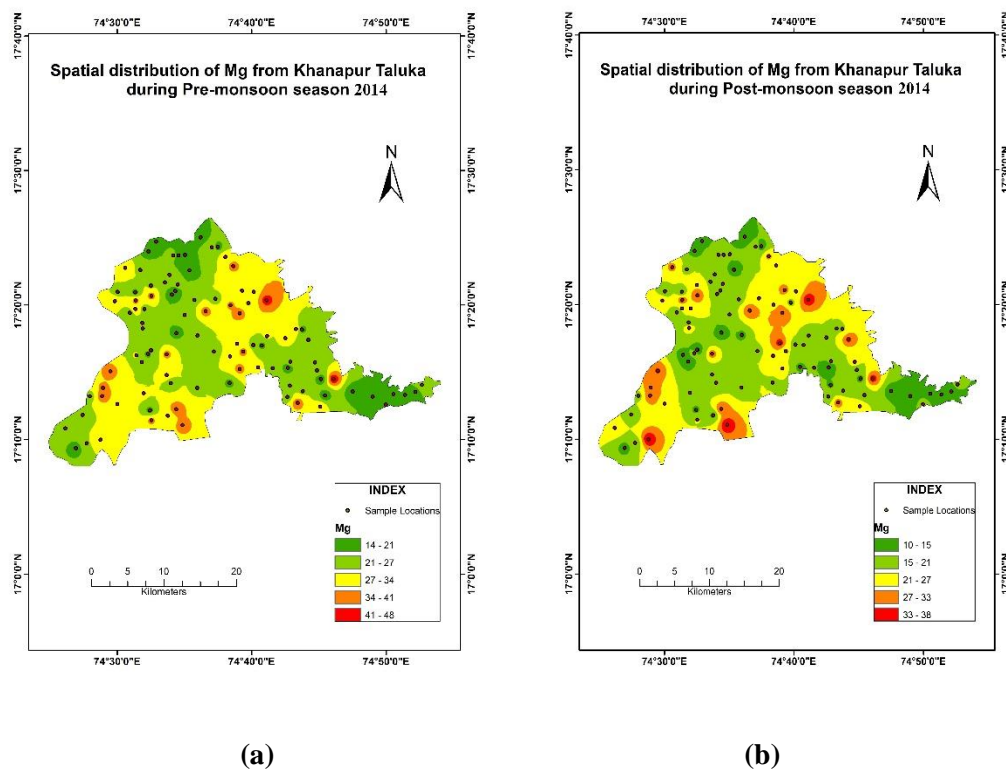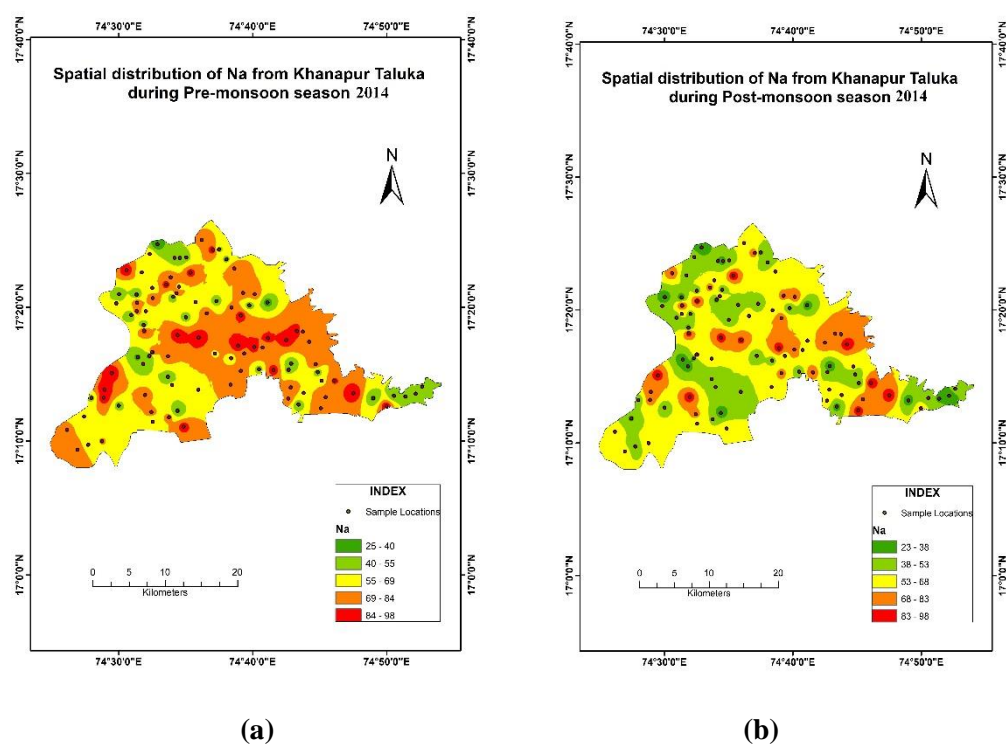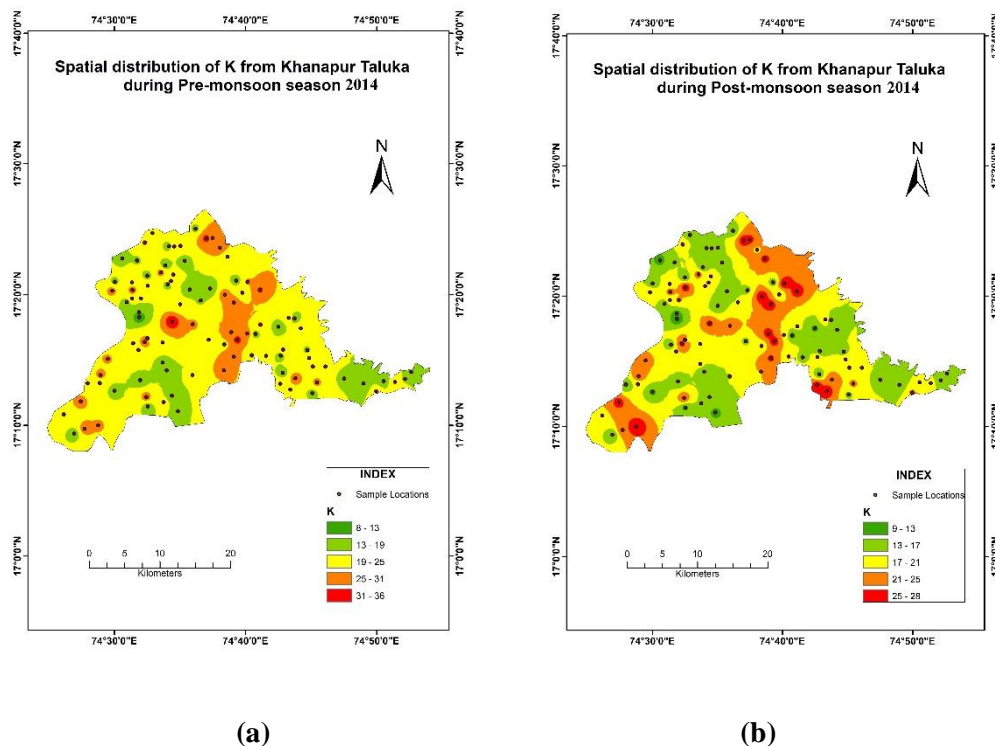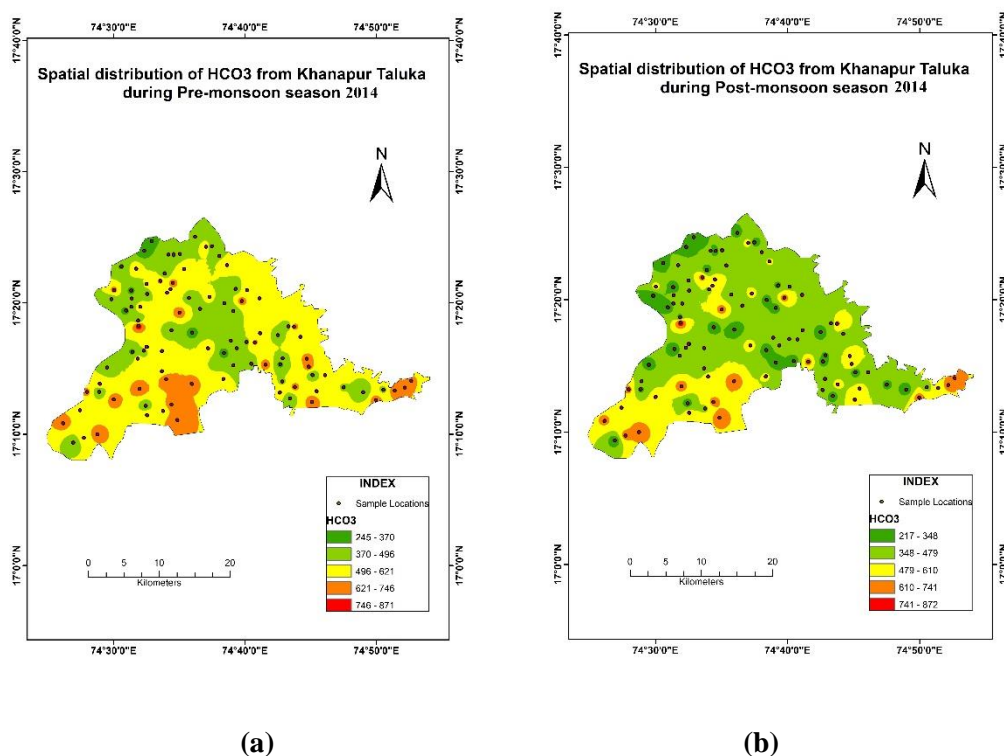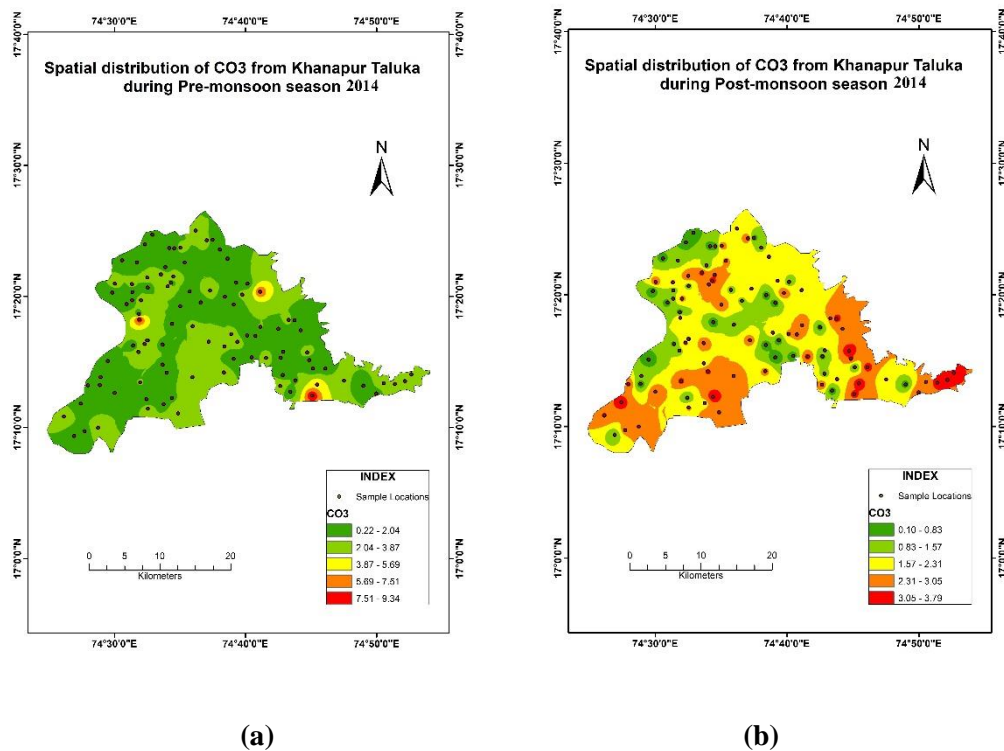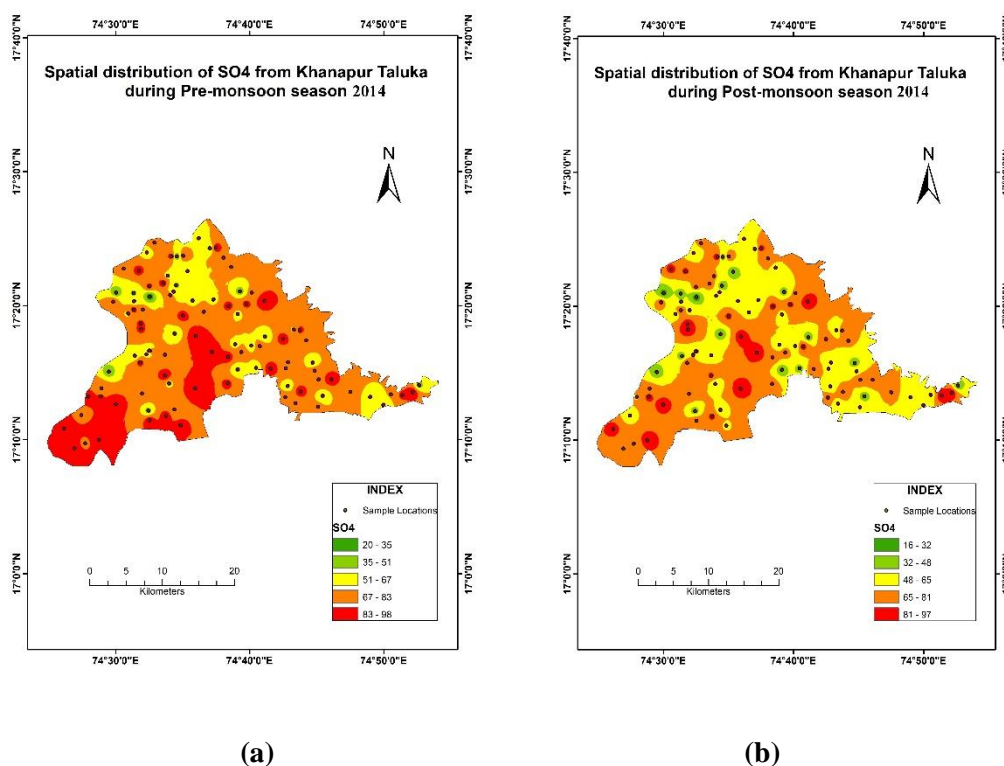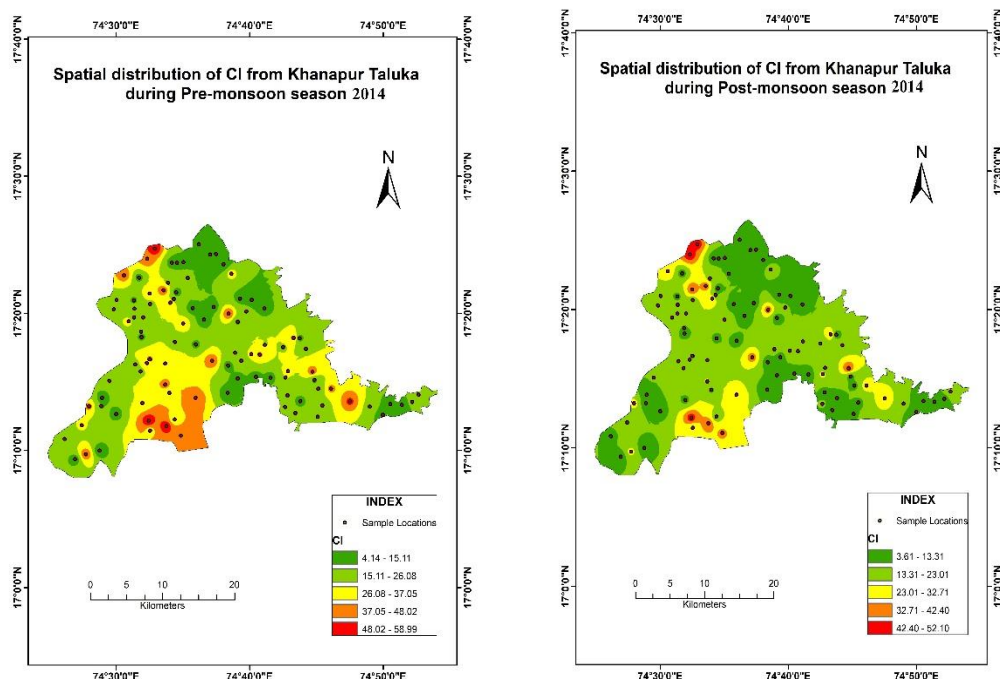
(a)   (b)
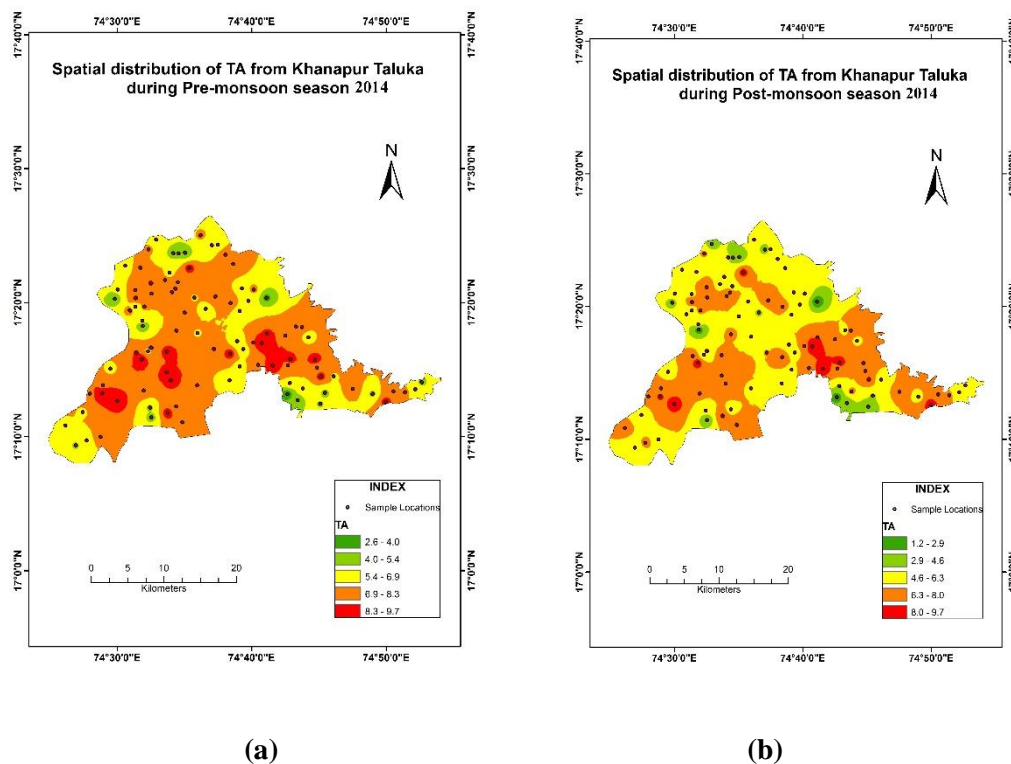
Fig. 2.3 Spatial distribution of TA during Pre and Post monsoon season 2014.

(a)   (b)
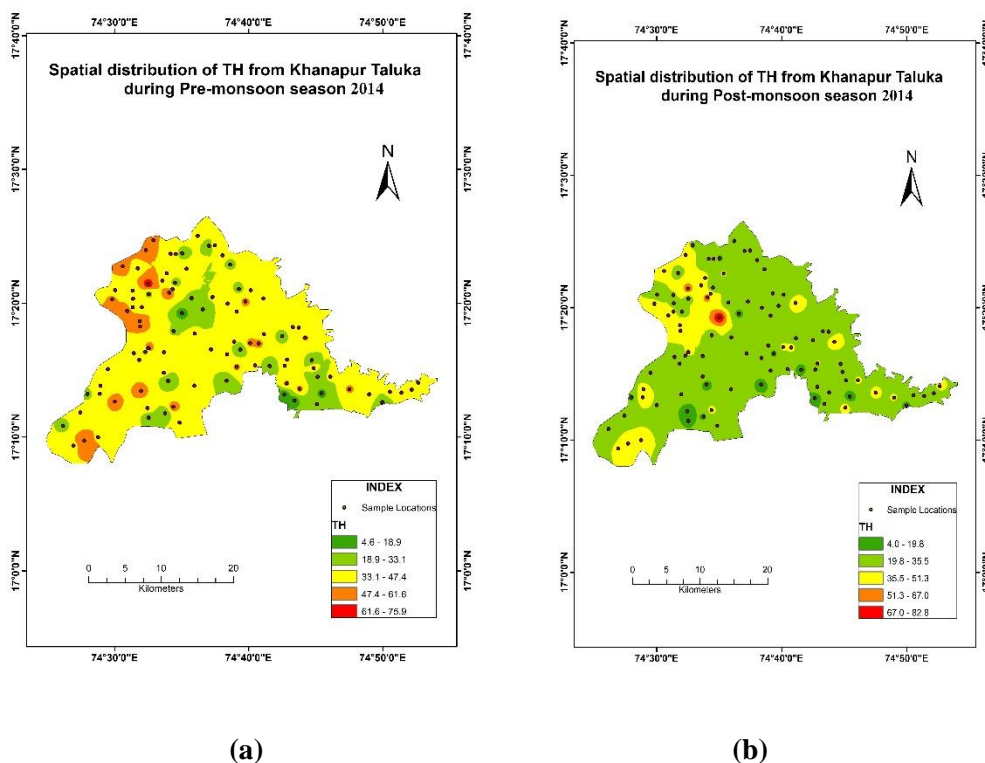
Fig. 2.4 Spatial distribution of TH during Pre and Post monsoon season 2014.

(a)   (b)

Fig. 2.5 Spatial distribution of TDS during Pre and Post monsoon season 2014.

(a)   (b)

Fig. 2.6 Spatial distribution of Ca during Pre and Post monsoon season 2014.

(a)   (b)

Fig. 2.7 Spatial distribution of Mg during Pre and Post monsoon season 2014.

(a)   (b)

Fig. 2.8 Spatial distribution of Na during Pre and Post monsoon season 2014.

(a)   (b)

Fig. 2.9 Spatial distribution of K during Pre and Post monsoon season 2014.

(a)   (b)

Fig. 2.10 Spatial distribution of HCO3 during Pre and Post monsoon season 2014.

(a)   (b)

Fig. 2.11 Spatial distribution of CO3 during Pre and Post monsoon season 2014.

(a)   (b)

Fig. 2.12 Spatial distribution of SO4 during Pre and Post monsoon season 2014.

<center>(a)   (b)</center>

Fig. 2.13 Spatial distribution of Cl during Pre and Post monsoon season 2014.

Classification of Groundwater based on Piper's Trilinear diagram

To comprehend the variance in hydrochemical facies, the results of chemical tests of groundwater samples have been displayed on the Piper's trilinear diagram (Fig. 3a and b).

As can be seen from Fig. 3.a & b, the hydrochemical facies of the pre and post-monsoon seasons of 2014 are 100% represented by alkaline earths over alkalies (Ca + Mg > Na + K). Similar to this, 100 water samples (100%) from 2014's pre- and post-monsoon seasons (HCO3 + CO3 > Cl + SO4) belong to weak acid exceed strong acid hydrochemical facies.
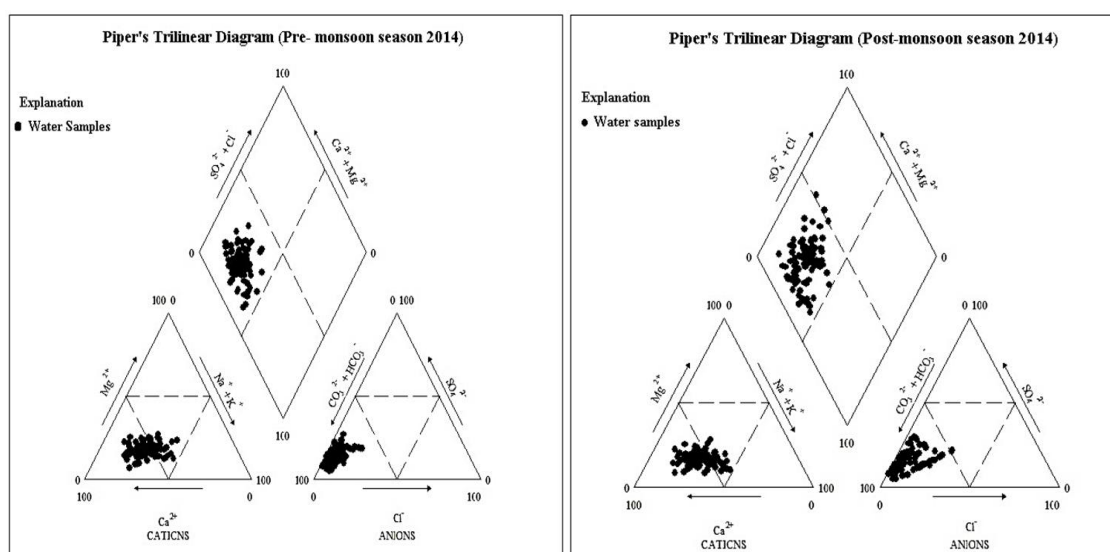
<center>a. Pre-monsoon season   b. Post-monsoon season</center>

Fig. 3.a & b: Piper Trilinear diagram from dug well and bore well water samples of the Study area.

Groundwater classification based on U.S. Salinity diagram

It has been attempted to categorise groundwater according to its suitability for irrigation in relation to alkali and salinity dangers (U.S. Salinity Laboratory Staff, 1954). On the USSL staff diagram (Fig. 4. a to d), the electrical conductivity (EC) and SAR values for each sample taken from the area are displayed.

According to Fig. 4.a and b, out of 35 samples of pre-monsoon well water, 12 samples (34.29%) and 5 samples (14.29%) are classified as C2 - S2 and C2 - S1, respectively, indicating good water quality for irrigation. 15 samples (42.86%) belong to C3-S2, indicating bad irrigation water quality, while 3 samples (8.57%) belong to C3-S1, indicating medium irrigation water quality. 18 samples (51.43%) from the post-monsoon season and 4 samples (11.43%) that belong to the C2 - S2 and C2 - S1 types, respectively, indicate adequate water quality for irrigation. Two samples (5.71%) fit the C3-S1 type, indicating that the water is of a medium quality for irrigation. 10 samples (28.57%) are of the C3-S2 type, indicating poor irrigation water quality, and 1 sample (2.28%) is of the C3-S3 type, indicating extremely poor irrigation water quality.

Similarly, it can be shown from Figures 4.c and 4.d that out of 65 bore well water samples taken in the pre-monsoon season, 4 samples (6.15%), 14 samples (21.54%), and correspondingly, belong to the C2 - S1 and C2 - S2 types, indicating good water quality for irrigation. Indicating medium water quality for irrigation, 4 samples (6.15%) fall into the C2–S3 class. The C3 - S2 type comprises 38 samples (58.46%) while the C3 - S3 type has 5 samples (7.69%), both of which indicate poor irrigation water quality. In the post-monsoon season, acceptable water quality for irrigation was indicated by the fact that 15 samples (23.08%) and 10 samples (15.38%), respectively, belonged to the C2 - S1 and C2 - S2 types. 15 samples (23.88%) fit the C3-S1 type, indicating that the irrigation water is of medium grade. 22 samples (33.85%) are of the C3-S2 type, which indicates poor water quality for irrigation, and 3 samples (4.62%) are of the C3-S3 type, which indicates extremely poor water quality for irrigation.
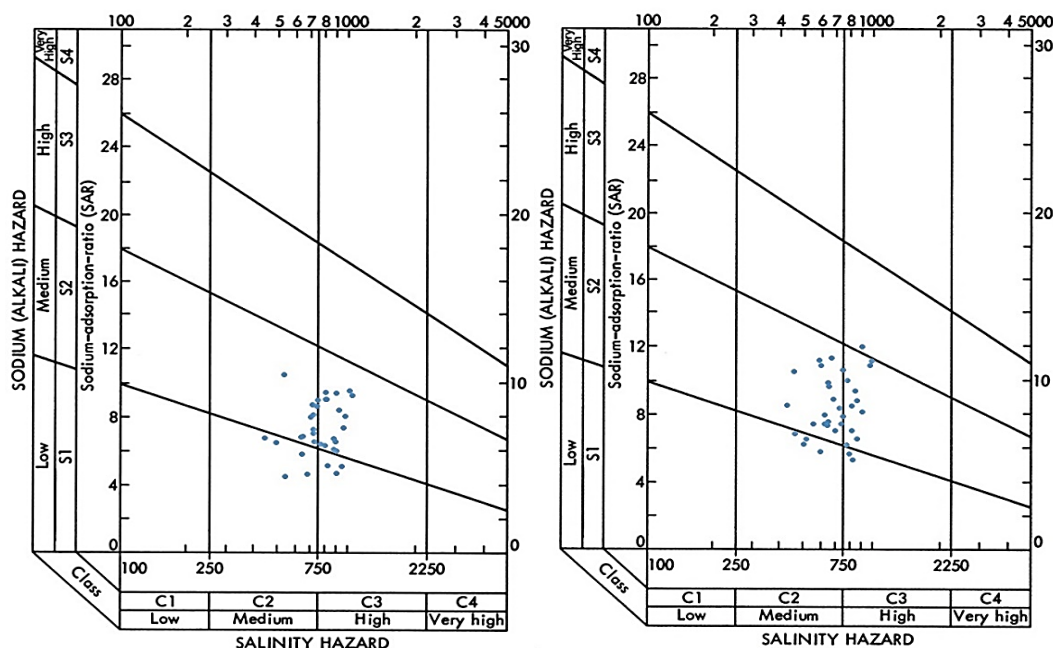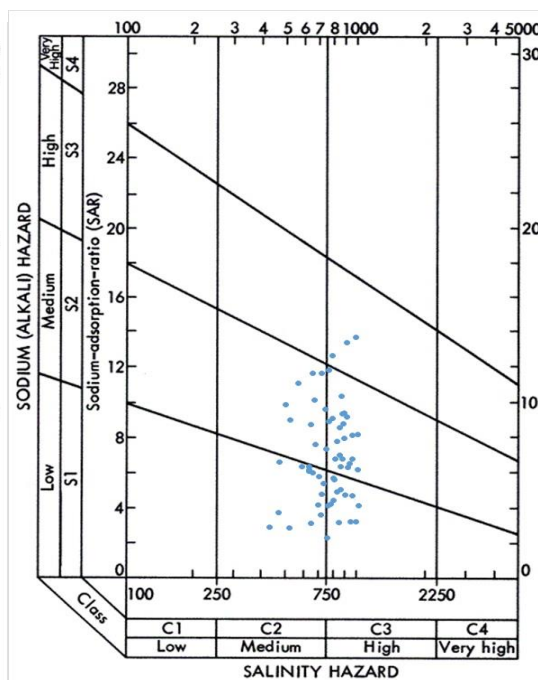

a. Pre - monsoon season   b. Post - monsoon season

Fig. 4. a-b: Classification of irrigation water from dug well water samples of Study area.
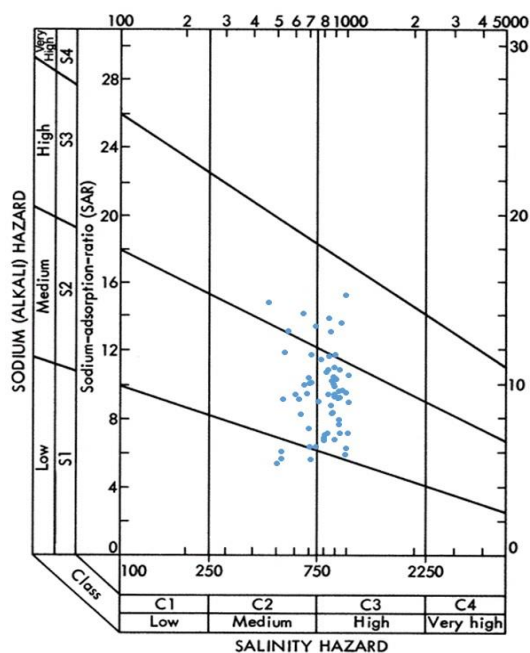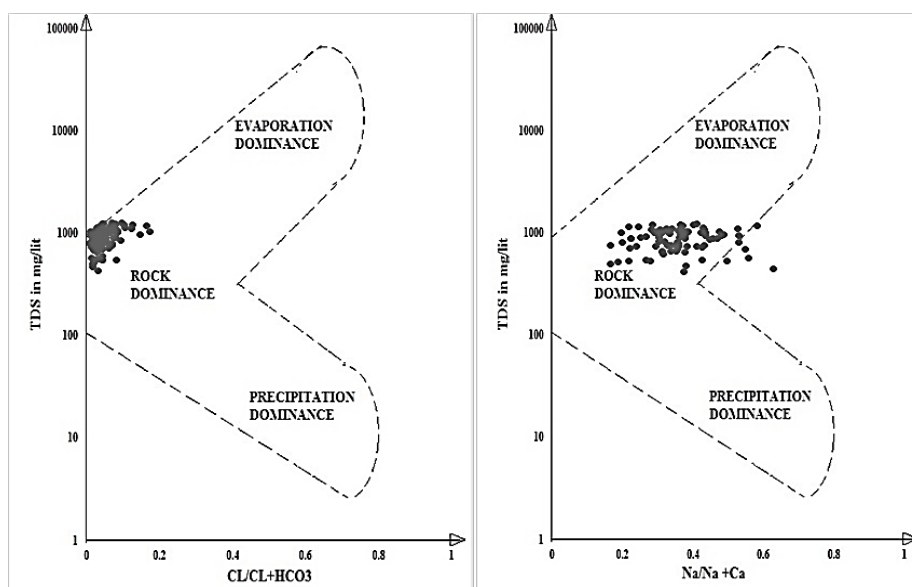
| c. Pre - monsoon season | d. Post - monsoon season |

Fig. 4. c-d: Classification of irrigation water from bore well water samples of Study area.

Classification of Groundwater based on Gibbs Variation diagram

According to the Gibbs variation diagram, precipitation, evaporation, and the dominance of rocks all affect the chemistry of groundwater (Gibbs, 1970). Figures 5a and b show the values of total dissolved solids (TDS), Na/Na + K, TDS, and Cl/Cl+HCO3 for all groundwater samples taken from the research region.

All 100 groundwater samples from the pre- and post-monsoon seasons are shown in Fig. 5. (a & b), indicating that rock dominance is the factor that controls the chemistry of the groundwater.

Fig. 5.a: Gibbs variation diagram for dug well and bore well water samples of the study area. (Pre - monsoon season 2014).
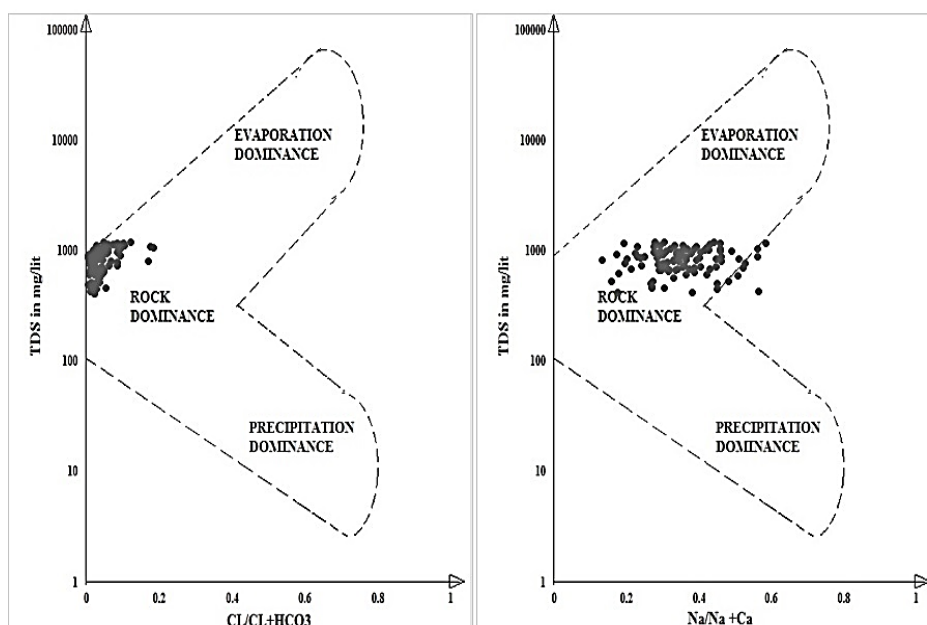
Fig. 5. b: Gibbs variation diagram for dug well and bore well water samples of the study area. (Post - monsoon season 2014).

CONCLUSIONS:

100% of the pre- and post-monsoon groundwater samples in Khanapur Taluka, Sangli District, exhibit the hydrochemical facies Ca + Mg > Na + K (alkaline earths exceed alkalies), according to analysis of the chemical composition of dug well and bore well water samples. In a similar vein, pre- and post-monsoon seasons, 100% of dug well and bore well water samples belong to the hydrochemical facies HCO_3 + CO_3 > Cl + SO_4 (weak acid exceeds strong acid). Twelve (34.29%) and five (14.29%) of the 35 dug well water samples taken in the pre-monsoon season fall into the C2 - S2 and C2 - S1 categories, respectively, indicating good water quality for irrigation. 15 samples (42.86%) belong to C3-S2, which indicates poor water quality for irrigation, whereas 3 samples (8.57%) belong to C3-S1, which indicates medium water quality for irrigation. In the post-monsoon season, there were 18 samples (51.43%) that were of the C2 - S2 type and 4 samples (11.43%) that were of the C2 - S1 type, indicating good irrigation water quality. Indicating medium water quality for irrigation, 2 samples (5.71%) are of the C3 - S1 type. Ten samples (28.57%) are belonging to the C3-S2 type, which indicates bad irrigation water quality, and one sample (2.28%) corresponds to the C3-S3 type, which indicates very bad irrigation water quality. likewise, out of 65 bore well water samples taken in the pre-monsoon season, 4 samples (6.15%), and 14 samples (21.54%), respectively, correspond to the C2 - S1 and C2 - S2 types, indicating high water quality for irrigation. A medium water quality for irrigation is indicated by the C2 - S3 type in 4 samples (6.15%), which is present. 38 samples (58.46%) belong to the C3-S2 type, which indicates bad water quality for irrigation, and 5 samples (7.69%) belong to the C3-S3 type, which represents very bad water quality for irrigation. A excellent water quality for irrigation is indicated by the fact that in the post-monsoon season, 15 samples (23.08%) and 10 samples (15.38%), respectively, belong to the C2 - S1 and C2 - S2 types. Indicating medium water quality for irrigation, 15 samples (23.08%) are of the C3-S1 type. The C3 - S2 type comprises 22 samples (33.85%), and the C3 - S3 type comprises 3 samples (4.62%), both of which indicate very poor irrigational water quality. According to the Gibbs variation diagram, the predominance of rocks affects round water chemistry.

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