Spatial and Seasonal Variability of Physico-Chemical Characteristics of Ground Water in Bassi Tehsil, Jaipur, Rajasthan, India

Swati Saxena*, Umesh Saxena[#], A.K. Sinha[+]

**Associate Professor, Department of Chemistry, Rajasthan College of Engineering for Women, Bhakrota, Jaipur, Rajasthan, India. swati.snigdha11@gmail.com*

[#]Principal, U.S. Ostwal College of Science, Chittorgarh, Rajasthan, India.

[+]Director, School of Basic Sciences, Manipal University, Jaipur, Rajasthan, India

***Abstract*- The study was aimed to analyze the spatial and seasonal variability of physico-chemical parameters of ground water quality in Bassi Tehsil of District Jaipur, Rajasthan, India in order to assess its suitability for drinking purpose. For this ground water samples from 71 sampling sites of 50 villages of study area were collected from tube wells and hand pumps of varying depths in pre and post monsoon seasons and analyzed for ten physico-chemical parameters namely pH, Total Alkalinity, Total Hardness, Calcium, Magnesium, Chloride, Nitrate, Fluoride, Total Dissolved Solid and Electrical Conductivity. Analysis of results showed that almost all parameters were exceeding the desirable limits prescribed by BIS, ICMR and WHO. But, by analyzing the data on the basis of highest permissible limits of the parameters, the observed principal ground water pollutants are total alkalinity, chloride, nitrate, fluoride, total dissolved solids (TDS) and electrical conductivity (EC). The study helps to understand the quality of water as well as to develop suitable management practices to protect the groundwater sources. Based on these results, it is also recommended to use water only after proper treatment for drinking purpose by the individuals to prevent adverse health effects.**

Keywords: **Ground Water Quality, Physico-chemical parameters, Spatial and seasonal variability, Bassi Tehsil and Rajasthan.**

I. INTRODUCTION

Water is an essential natural resource for sustaining life and environment but over the last few decades the water quality is deteriorating due to it's over exploitation. It has raised certain basic challenges in our environment and we are suffering both the problems of quality and quantity of water. Water quality is indispensable parameter to be studied when the overall focus is sustainable development keeping mankind at focal point. Groundwater is the major source of drinking water in rural as well as in urban areas and in Rajasthan and over 94% of the drinking water demand is met by groundwater.

In Rajasthan water is not only saline but it also contain many dissolved substances, due to which water is not suitable for drinking. These substances have either the toxic effects on the consumer or have long terms indirect effects [1, 2, 3]. Other than salinity, presence of many metal ions, chloride, sulphate, nitrate and fluoride are the major factors of the water quality, which influence badly the human health [4].

All the 33 districts of Rajasthan have been declared as fluorosos is prone areas. The worst are- Nagaur, Jaipur, Sikar, Jodhpur, Barmer, Ajmer, Sirohi, Jhunjhunu, Churu, Bikaner, Ganganagar etc. [5, 6]. Nitrate is also one of the most common groundwater contaminants in Rajasthan. Ajmer, Alwar, Banaswara, Baran, Barmer, Bundi, Bharatpur, Bhilwara, Bikaner, Chittaurgarh, Churu, Dausa, Dhaulpur, Dungarpur, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhalawar, Jhunjhununu, Jodhpur, Karauli, Kota, Nagaur, Pali, Partapgarh, Rajsamand, Sirohi, Sikar, Sawai Madhopur, Tonk, Udaipur districts have been reported nitrate concentration more than 45 mg/L [7].

In Amer, Bassi, Chomu, Jamwa Ramgarh, Kotputali, Shahpura and Virat Nagar tehsils of Jaipur district there is the problem of high fluoride and nitrate concentrations in groundwater [8].

II. EXPERIMENTAL

A. Study Area

Rajasthan is known as "the land of king" and it is the largest state of the republic of India in terms of geographical spread. It is situated in the North- Western part of India having total area is around 3,42,239 Sq. Km. which represents 10.41 % of total area of the country and population of 6.86 Crores spread over in 44,672 villages, which is 5.67 % of nations population but being just available 1% of the total water resources of the country. The state has extreme climatic and geographical condition and it suffers both the problems of quantity and quality of water [9, 10].

Jaipur, the capital of Rajasthan, has a total area of 11,117 Sq. Km. covering the 3.23% of the total area of the state, administered by 13 tehsils or sub-divisions. Our focused area of study is Bassi tehsil, out of the 13 tehsils of Jaipur

district. The area of tehsil is 654.69 sq.km, located at $26^0$96' N latitude and $75^0$62'E longitude. In Bassi Tehsil there are 210 villages (famous for their leather footwear and Embroidery beading). In the study area there are no major surface water sources however; main sources of drinking water are open wells, hand pumps and bore wells [11, 12, and 13]. In Bassi Tehsil 84 villages are reported having fluoride concentration more than 1.5 ppm, 78 villages are exhibiting nitrate concentration more than 45 ppm and 30 villages are having Electrical conductivity more than 3000 micromhos/cm [12, 14]. Review of literature reveals that very few studies have been made to scientifically investigate the ground water contamination of the study area. The present study aims to analyze the spatial and seasonal variability of different physico-chemical parameters in most rural habitations of Bassi Tehsil of Jaipur, Rajasthan, India in order to assess the suitability of ground water for human uses and it also deals with the necessity of restoring the water quality.

B. Sample Collection

Ground water samples from a total of 71sampling sites of 50 villages of Bassi Tehsil were collected in pre-cleaned and rinsed polyethene bottles of two litre capacity with necessary precautions [15]. The total water collection in the year of 2013 is divided in to two seasons, one is pre monsoon and another one is post monsoon. The sampling is carried out, during April 2013 for pre monsoon season and in September-October 2013 for post monsoon season from manually operated tube wells and hand pumps of varying depth.

C. Physico-chemical Analysis

All the samples were analyzed for the following Physico-chemical parameters; pH, Total Alkalinity (TA), Total Hardness (TH), Calcium hardness (Ca H), Magnesium hardness (Mg H), Chloride, Nitrate, Fluoride, Total Dissolved Solid (TDS) and Electrical Conductivity (EC). The analysis of water samples were carried out in accordance to standard analytical methods [16]. All the chemicals used were of AR grade and double distilled water used for preparation of solutions. Details of the analysis methods are summarized in Table 1.

Table 1: Parameters and methods employed in the physicochemical examination of water samples

S.No.	Parameters	Unit	Method Employed
1.	pH	-	Digital pH-meter
2.	Total Alkalinity	mg/L	Titrimetric method (With H_2SO_4)
3.	Total Hardness (as $CaCO_3$)	mg/L	Titrimetric method (With EDTA)
4.	Calcium Hardness (as $CaCO_3$)	mg/L	Titrimetric method
5.	Magnesium Hardness (as $CaCO_3$)	mg/L	Titrimetric method
6.	Chloride (as Cl^-)	mg/L	Titrimetric method (With $AgNO_3$)
7.	Nitrate (as NO_3^-)	mg/L	Spectrophotometric method
8.	Fluoride (as F^-)	mg/L	Ion Selective Electrode
9.	Total Dissolved Solids	mg/L	Digital TDS-meter
10.	Electrical Conductivity	µmhos/cm	Digital Conductivity-meter

III. RESULT AND DISCUSSION

A. *Spatial Variation of Physico-chemical Parameters*

The analytical results of water quality parameters are reported in Table 2 and 3. Ground water quality depends upon the location and state of environmental protection in that given particular area. The results are discussed for potability as per the standards by BIS, ICMR and WHO. The discussion includes spatial variation of water quality with respect to sampling sites.

As per the graphs generated (Fig. 1-10), representing spatial variation of the parameters it is inferred that almost all or a lot of samples are exceeding the desirable limit of parameters. But, by analyzing the data on the basis of highest permissible limits of the parameters, the observed principal ground water pollutants are total alkalinity, chloride, nitrate, fluoride, total dissolved solids (TDS) and electrical conductivity (EC) exceeding 250 mg/L, 1000 mg/L, 45 mg/L, 1.5 mg/L, 1500 mg/L and 1400 µmhos/cm respectively.

Table 2: Physico-Chemical Characteristics of Groundwater Samples – Pre Monsoon Season

S.No.	Village	Source	Sample No.	pH	Alkalinity	TH	CaH	Ca^{+2} ions	MgH	Mg^{+2} ions	Cl^-	NO_3^-	F^-	TDS	EC
1	Akhepura	HP	S1	7.9	411	529	237	94.8	292	70.95	400	56	0.71	2216	3165
		TW	S2	8.4	305	115	43	17.2	72	17.49	31	15	1.44	778	1111
2	Anantpura	HP	S3	7.9	748	360	151	60.4	209	50.78	278	22	0.37	2100	3000
		TW	S4	8.3	462	161	67	26.8	94	22.84	176	18	1.8	1470	2100
3	Banskho	HP	S5	7.5	651	516	172	68.8	344	83.59	137	28	2.12	1696	2422
		TW	S6	8.4	396	105	40	16	65	15.79	123	12	1.99	1298	1855
4	Barala	HP	S7	7.5	586	192	78	31.2	114	27.7	333	78	2.05	2146	3065

S.No.	Village	Source	Sample No.	pH	Alkalinity	TH	CaH	Ca^{+2} ions	MgH	Mg^{+2} ions	Cl^-	NO_3^-	F^-	TDS	EC
5	Bassi	HP	S8	8.4	258	158	64	25.6	94	22.84	202	86	1.14	1590	2271
		TW	S9	7.8	333	156	67	26.8	89	21.62	163	44	0.79	1191	1701
6	Benada	HP	S10	7.6	435	732	336	134.4	396	96.22	315	131	0.93	1740	2486
7	Bharampur	HP	S11	7.7	368	188	78	31.2	110	26.73	176	20	0.42	920	1314
8	Chainpuriya	HP	S12	7.7	562	115	46	18.4	69	16.76	80	12	1.3	1034	1477
9	Chapariya	HP	S13	7.7	426	163	70	28	93	22.59	60	70	1.13	760	1085
10	Charangarh	HP	S14	7.4	243	264	121	48.4	143	34.74	33	29	0.71	792	1131
11	Chatarpura	HP	S15	7.6	707	112	45	18	67	16.28	65	19	4.67	1200	1714
12	Danau Kalan	HP	S16	8.2	582	46	22	8.8	24	5.83	20	22	1.4	1055	1507
13	Danau Khurd	HP	S17	7.7	409	568	206	82.4	362	87.96	484	8	0.9	2644	3777
		TW	S18	8.2	458	284	121	48.4	163	39.6	140	22	2.9	1680	2400
14	Garh	HP	S19	8.1	651	108	44	17.6	64	15.55	361	118	1	1962	2803
15	Ghasipura	HP	S20	8.4	344	88	32	12.8	56	13.6	20	38	0.03	847	1210
		TW	S21	8.3	766	74	33	13.2	41	9.96	51	26	11.4	1613	2304
16	Ghata	HP	S22	7.1	402	437	198	79.2	239	58.07	601	11	0.86	2593	3704
		TW	S23	7.3	467	632	297	118.8	335	81.4	468	14	0.7	2171	3101
17	Gudha Meena	HP	S24	7.8	423	160	66	26.4	94	22.84	23	18	0.27	980	1400
18	Gumanpura	HP	S25	7.8	460	317	128	51.2	189	45.92	380	16	0.88	2310	3300
		TW	S26	7.9	595	528	238	95.2	290	70.47	259	72	1.4	1764	2520
19	Gwalini	HP	S27	7.9	520	374	171	68.4	203	49.32	22	8	1.8	1333	1904
20	Hans Mahal	HP	S28	7.6	157	424	187	74.8	237	57.59	220	7	0.32	1182	1688
21	Hanumanpura	HP	S29	7.7	552	123	51	20.4	72	17.49	83	27	0.8	967	1381
		TW	S30	8.2	784	67	23	9.2	44	10.69	95	24	12.5	1473	2104
22	Jhajhwar	HP	S31	7.4	523	668	283	113.2	385	93.55	1430	58	0.41	4235	6050
		TW	S32	8.4	254	109	45	18	64	15.55	107	45	0.8	980	1400
23	Jhar	HP	S33	7.9	412	233	102	40.8	131	31.83	44	37	0.65	960	1371
24	Kalyanpura	HP	S34	8.5	527	89	36	14.4	53	12.87	28	34	1.3	1122	1603
		TW	S35	8.2	530	65	22	8.8	43	10.44	41	16	1.8	1190	1700
25	Kaneta	HP	S36	7.8	286	364	144	57.6	220	53.46	1424	6	0.11	4762	6802
		TW	S37	8.4	564	77	34	13.6	43	10.44	40	14	0.7	1050	1500
26	Kaneti	HP	S38	7.5	586	867	322	128.8	545	132.43	1075	236	1.06	4890	6985
27	Kanota	HP	S39	8.3	409	203	90	36	113	27.45	296	33	0.62	1835	2621
		TW	S40	8.4	741	91	36	14.4	55	13.36	225	8	1.7	1983	2833
28	Kashipura	HP	S41	7.5	695	105	40	16	65	15.79	90	21	3.2	1305	1864
29	Keshopura	HP	S42	7.6	555	350	140	56	210	51.03	644	5	0.75	2520	3600
30	Kuthada Kalan	HP	S43	7.1	233	66	25	10	41	9.96	20	22	0.77	709	1013
31	Lalgarh	HP	S44	7.6	510	284	122	48.8	162	39.36	230	15	1.42	1240	1771
32	Mundali	HP	S45	7.7	482	117	46	18.4	71	17.25	55	12	4.2	1321	1887
		TW	S46	8.2	734	90	34	13.6	56	13.6	152	26	3.38	1682	2404
33	Nagal Karna	HP	S47	7.4	371	154	57	22.8	97	23.57	60	11	4.35	1295	1850

S.No.	Village	Source	Sample No.	pH	Alkalinity	TH	CaH	Ca^{+2} ions	MgH	Mg^{+2} ions	Cl^-	NO_3^-	F^-	TDS	EC
		TW	S48	8.1	795	73	32	12.8	41	9.96	80	26	5.9	1610	2300
34	Parasoli	HP	S49	7.7	412	774	397	158.8	377	91.61	320	2	1.17	2146	3065
		TW	S50	8.4	464	78	35	14	43	10.44	60	23	2.2	1050	1500
35	Parempura	HP	S51	7.8	431	641	283	113.2	358	86.99	444	18	1.15	3474	4963
36	Patan	HP	S52	7.1	655	622	264	105.6	358	86.99	885	10	0.52	3535	5050
37	Peepalabai	HP	S53	7.2	160	374	209	83.6	165	40.09	266	82	1.84	1680	2400
		TW	S54	8.2	435	400	185	74	215	52.24	65	26	8.95	1505	2150
38	Peipura	HP	S55	7.8	532	267	118	47.2	149	36.2	250	11	1.35	1750	2500
		TW	S56	8.4	435	110	40	16	70	17.01	35	28	1.5	875	1250
39	Rajwas	HP	S57	7.6	648	463	205	82	258	62.69	551	52	1.33	2306	3295
40	Ramser	HP	S58	7.3	520	254	103	41.2	151	36.69	60	18	3.8	1050	1500
		TW	S59	8.4	464	118	44	17.6	74	17.98	50	25	2	1053	1504
41	Ratanpura	HP	S60	7.9	532	299	135	54	164	39.85	80	32	1.02	1435	2050
		TW	S61	8.4	552	88	35	14	53	12.87	60	19	1.07	1129	1613
42	Roopura	HP	S62	7.5	263	107	42	16.8	65	15.79	130	24	1.44	1113	1590
		TW	S63	8.1	415	430	200	80	230	55.89	81	25	8.75	1610	2300
43	Sambhariya	HP	S64	7.4	314	232	96	38.4	136	33.04	58	14	0.07	356	508
44	Shankarpura	HP	S65	7.6	588	134	53	21.2	81	19.68	58	6	4.2	1028	1469
45	Siya Ka Bas	HP	S66	7.7	235	234	98	39.2	136	33.04	62	91	0.85	1225	1750
46	Tehda	HP	S67	8.2	276	145	62	24.8	83	20.16	221	20	1.4	1478	2111
47	Tekchandpura	HP	S68	7.8	328	306	133	53.2	173	42.03	40	14	0.2	563	804
48	Tilpatti	HP	S69	7.8	642	194	81	32.4	113	27.45	80	14	0.9	1280	1828
49	Todabhata	HP	S70	8.5	328	65	22	8.8	43	10.44	52	24	2	984	1405
50	Tunga	HP	S71	7.6	36	38	16	6.4	22	5.34	15	10	0.1	63	86

Where- TA = Total Alkalinity, TH = Total Hardness, CaH = Calcium Hardness, MgH = Magnesium Hardness, Cl^- = Chloride, NO_3^- = Nitrate, F^- = Fluoride, TDS = Total Dissolved Solids, EC = Electrical Conductivity.
All parameters are expressed in mg/L except pH and EC. EC is expressed in µmhos/cm.
Ca^{+2} = Ca mg/L (as $CaCO_3$), Mg^{+2} = Mg mg/L (as $CaCO_3$).
HP = Hand Pump, TW = Tube Well.

Table 3: Physico-Chemical Characteristics of Groundwater Samples – Post Monsoon Season

S. No.	Village	Source	Sample No.	pH	Alkalinity	TH	CaH	Ca^{+2} ions	MgH	Mg^{+2} ions	Cl^-	NO_3^-	F^-	TDS	EC
1	Akhepura	HP	S1	8.1	410	406	180	72	226	54.91	306	102	1.36	1581	2259
		TW	S2	8.6	294	82	32	12.8	50	12.15	22	21	1.94	616	880
2	Anantpura	HP	S3	7.7	607	284	122	48.8	162	39.36	194	15	0.85	1493	2132
		TW	S4	7.7	517	540	245	98	295	71.68	417	29	0.73	2074	2962
3	Banskho	HP	S5	7.8	580	478	173	69.2	305	74.11	193	31	0.92	1630	2328
		TW	S6	8.5	363	98	41	16.4	57	13.85	98	14	1.54	1207	1724
4	Barala	HP	S7	7.7	484	110	45	18	65	15.79	118	7	1.8	668	954

S. No.	Village	Source	Sample No.	pH	Alkalinity	TH	CaH	Ca^{+2} ions	MgH	Mg^{+2} ions	Cl^-	NO_3^-	F^-	TDS	EC
5	Bassi	HP	S8	7.6	459	161	68	27.2	93	22.59	171	94	0.81	1274	1820
		TW	S9	7.4	255	187	80	32	107	26	113	56	0.51	1356	1937
6	Benada	HP	S10	8.5	838	254	111	44.4	143	34.74	107	59	0.98	1612	2303
7	Bharampur	HP	S11	7.8	482	364	163	65.2	201	48.84	146	21	0.6	1044	1491
8	Chainpuriya	HP	S12	7.7	703	261	113	45.2	148	35.96	118	11	1	1206	1723
9	Chapariya	HP	S13	7.7	282	211	88	35.2	123	29.88	28	27	0.9	424	605
10	Charangarh	HP	S14	7.7	168	220	92	36.8	128	31.1	40	27	0.32	432	617
11	Chatarpura	HP	S15	7.6	698	147	63	25.2	84	20.41	60	18	2.6	956	1365
12	Danau Kalan	HP	S16	7.6	454	159	66	26.4	93	22.59	34	24	1.17	712	1018
13	Danau Khurd	HP	S17	7.2	312	660	237	94.8	423	102.8	103	106	0.45	910	1300
		TW	S18	7.8	382	337	151	60.4	186	45.19	84	29	2.6	1478	2111
14	Garh	HP	S19	7.8	422	777	392	156.8	385	93.55	355	94	1.02	1685	2407
15	Ghasipura	HP	S20	7.7	365	127	51	20.4	76	18.46	21	13	0.55	640	914
		TW	S21	7.9	817	92	37	14.8	55	13.36	54	19	11.9	1271	1816
16	Ghata	HP	S22	7.9	443	313	140	56	173	42.03	246	14	1.43	1414	2020
		TW	S23	7.7	514	501	217	86.8	284	69.01	367	17	0.96	1669	2384
17	Gudha Meena	HP	S24	7.6	403	199	88	35.2	111	26.97	20	19	0.4	642	917
18	Gumanpura	HP	S25	7.7	384	208	89	35.6	119	28.91	103	8	2	808	1154
		TW	S26	7.8	509	404	181	72.4	223	54.18	183	53	2.5	1205	1721
19	Gwalini	HP	S27	7.7	510	270	125	50	145	35.23	80	6	1.4	891	1273
20	Hans Mahal	HP	S28	7.6	476	1100	423	169.2	677	164.5	1455	20	2.08	5434	7763
21	Hanumanpura	HP	S29	7.1	560	316	144	57.6	172	41.79	507	95	1.6	2196	3137
		TW	S30	7.5	812	92	33	13.2	59	14.33	148	37	12.2	1837	2624
22	Jhajhwar	HP	S31	7.9	575	440	190	76	250	60.75	436	41	1.1	2204	3149
		TW	S32	8.6	278	76	31	12.4	45	10.93	154	38	1.08	647	924
23	Jhar	HP	S33	7.8	488	271	118	47.2	153	37.17	63	32	0.41	926	1322
24	Kalyanpura	HP	S34	7.8	256	307	134	53.6	173	42.03	30	18	0.8	487	696
		TW	S35	7.8	318	83	29	11.6	54	13.12	52	13	1.2	607	867
25	Kaneta	HP	S36	7.7	223	268	105	42	163	39.6	57	14	0.5	804	1148
		TW	S37	8.2	459	56	26	10.4	30	7.29	34	21	0.39	651	930
26	Kaneti	HP	S38	7.4	674	347	129	51.6	218	52.97	80	2	0.14	918	1312
27	Kanota	HP	S39	7.5	415	361	148	59.2	213	51.75	342	40	1.3	1436	2051
		TW	S40	7.8	689	134	61	24.4	73	17.73	266	11	2.3	1606	2294
28	Kashipura	HP	S41	7.6	411	161	64	25.6	97	23.57	86	19	1.35	910	1301
29	Keshopura	HP	S42	7.6	330	227	92	36.8	135	32.8	80	26	0.49	1333	1904
30	Kuthada Kalan	HP	S43	7.6	785	262	110	44	152	36.93	42	21	0.5	800	1142
31	Lalgarh	HP	S44	7.7	505	185	80	32	105	25.51	105	49	0.9	1042	1488
32	Mundali	HP	S45	7.8	600	106	42	16.8	64	15.55	92	21	5.6	1131	1616
		TW	S46	8.3	822	77	31	12.4	46	11.17	206	32	4.02	1951	2787
33	Nagal Karna	HP	S47	7.7	389	119	43	17.2	76	18.46	148	2	1.9	608	869

S. No.	Village	Source	Sample No.	pH	Alkalinity	TH	CaH	Ca^{+2} ions	MgH	Mg^{+2} ions	Cl^-	NO_3^-	F^-	TDS	EC
		TW	S48	8.5	859	53	21	8.4	32	7.77	112	19	3.25	822	1174
34	Parasoli	HP	S49	7.8	440	553	280	112	273	66.33	326	15	1.43	1322	1889
		TW	S50	8.5	516	48	22	8.8	26	6.31	56	34	1.8	693	990
35	Parempura	HP	S51	7.8	403	520	200	80	320	77.76	475	13	0.8	2880	4114
36	Patan	HP	S52	7.7	535	479	199	79.6	280	68.04	652	18	1.22	2468	3526
37	Peepalabai	HP	S53	7.8	206	228	123	49.2	105	25.51	58	25	0.5	408	583
		TW	S54	7.7	513	248	99	39.6	149	36.2	38	16	5.3	723	1033
38	Peipura	HP	S55	7.7	700	242	106	42.4	136	33.04	446	24	1.23	1946	2780
		TW	S56	8.2	504	97	34	13.6	63	15.3	47	41	1.3	1016	1451
39	Rajwas	HP	S57	7.6	704	428	183	73.2	245	59.53	320	27	1.3	2883	4118
40	Ramser	HP	S58	7.3	540	210	85	34	125	30.37	100	13	1.3	1040	1485
		TW	S59	8.3	483	89	27	10.8	62	15.06	66	21	1.06	924	1320
41	Ratanpura	HP	S60	7.8	860	260	113	45.2	147	35.72	193	8	1.13	1600	2286
		TW	S61	7.9	871	190	75	30	115	27.94	130	19	2.65	1440	2057
42	Roopura	HP	S62	7.8	353	243	110	44	133	32.31	60	30	1.4	722	1031
		TW	S63	8.4	511	627	283	113.2	344	83.59	58	28	8.49	1159	1656
43	Sambhariya	HP	S64	7.6	425	145	60	24	85	20.65	30	30	2.25	920	1314
44	Shankarpura	HP	S65	7.8	540	197	85	34	112	27.21	80	2	3.6	1125	1607
45	Siya Ka Bas	HP	S66	7.6	313	179	73	29.2	106	25.75	56	71	1.13	773	1104
46	Tehda	HP	S67	7.7	425	174	72	28.8	102	24.78	172	24	1.55	1140	1629
47	Tekchandpura	HP	S68	7.8	254	292	130	52	162	39.36	40	12	0.25	529	756
48	Tilpatti	HP	S69	7.8	633	366	153	61.2	213	51.75	114	22	0.76	1306	1867
49	Todabhata	HP	S70	7.8	550	129	54	21.6	75	18.22	63	20	1.8	1043	1490
50	Tunga	HP	S71	7.8	290	780	395	158	385	93.55	288	309	0.65	1604	2291

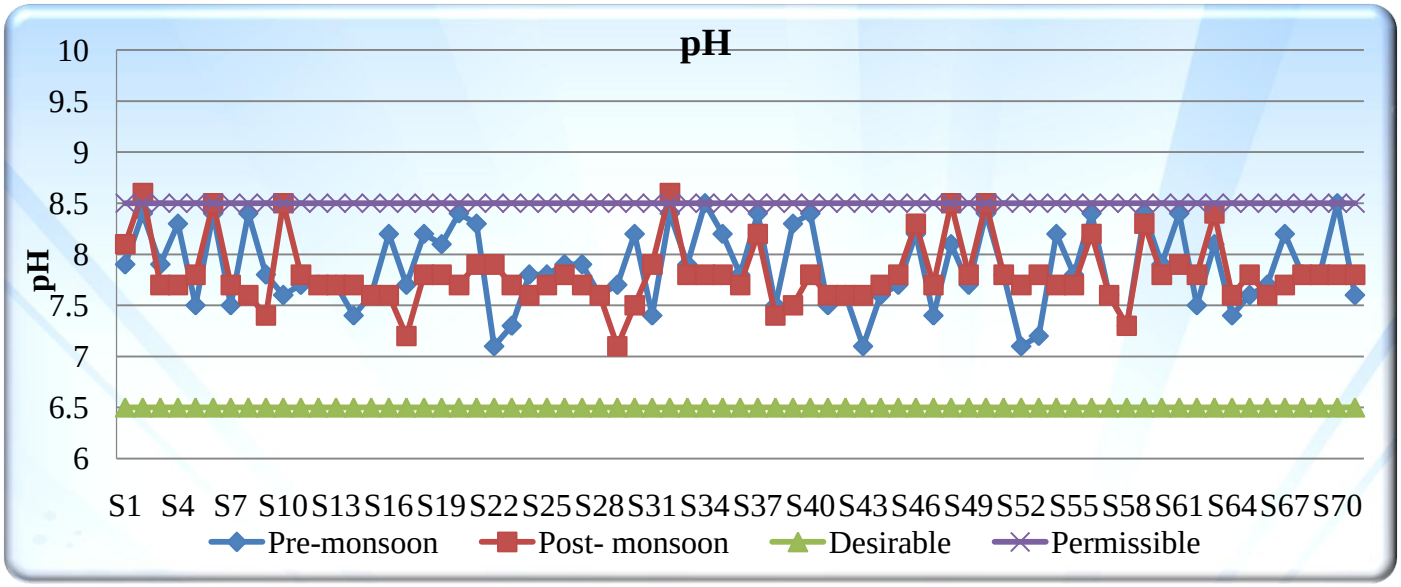

Figure 1: Spatial variation of pH in Pre and Post monsoon seasons

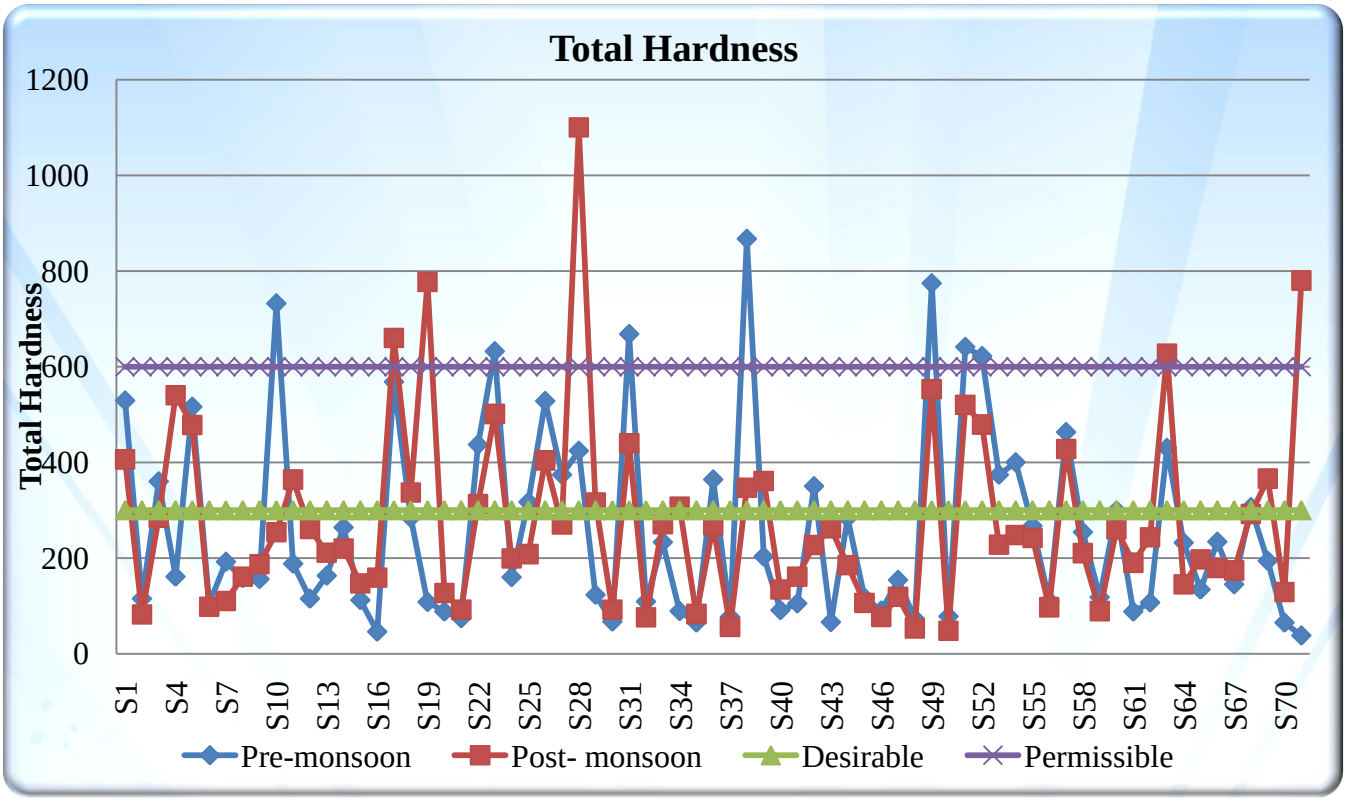

Figure 2: Spatial variation of Total Alkalinity in Pre and Post monsoon seasons

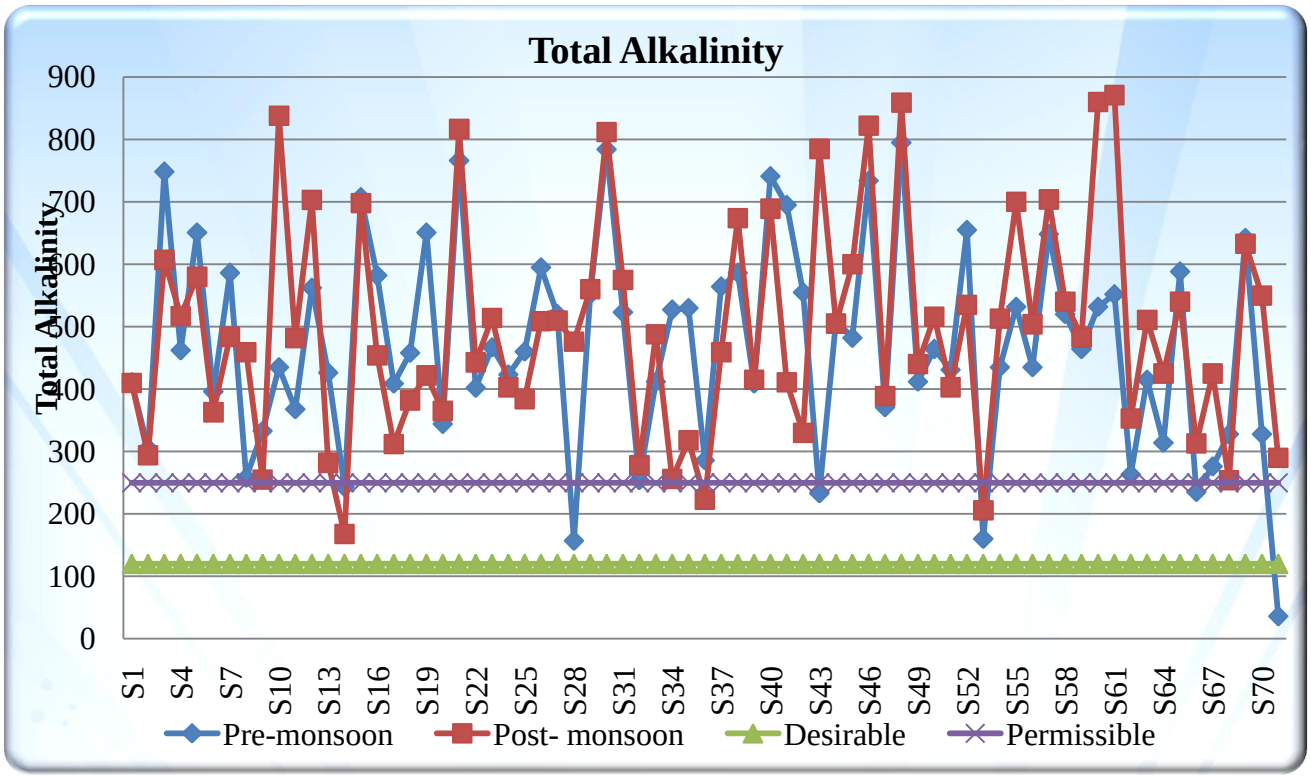

Figure 3: Spatial variation of Total Hardness in Pre and Post monsoon seasons

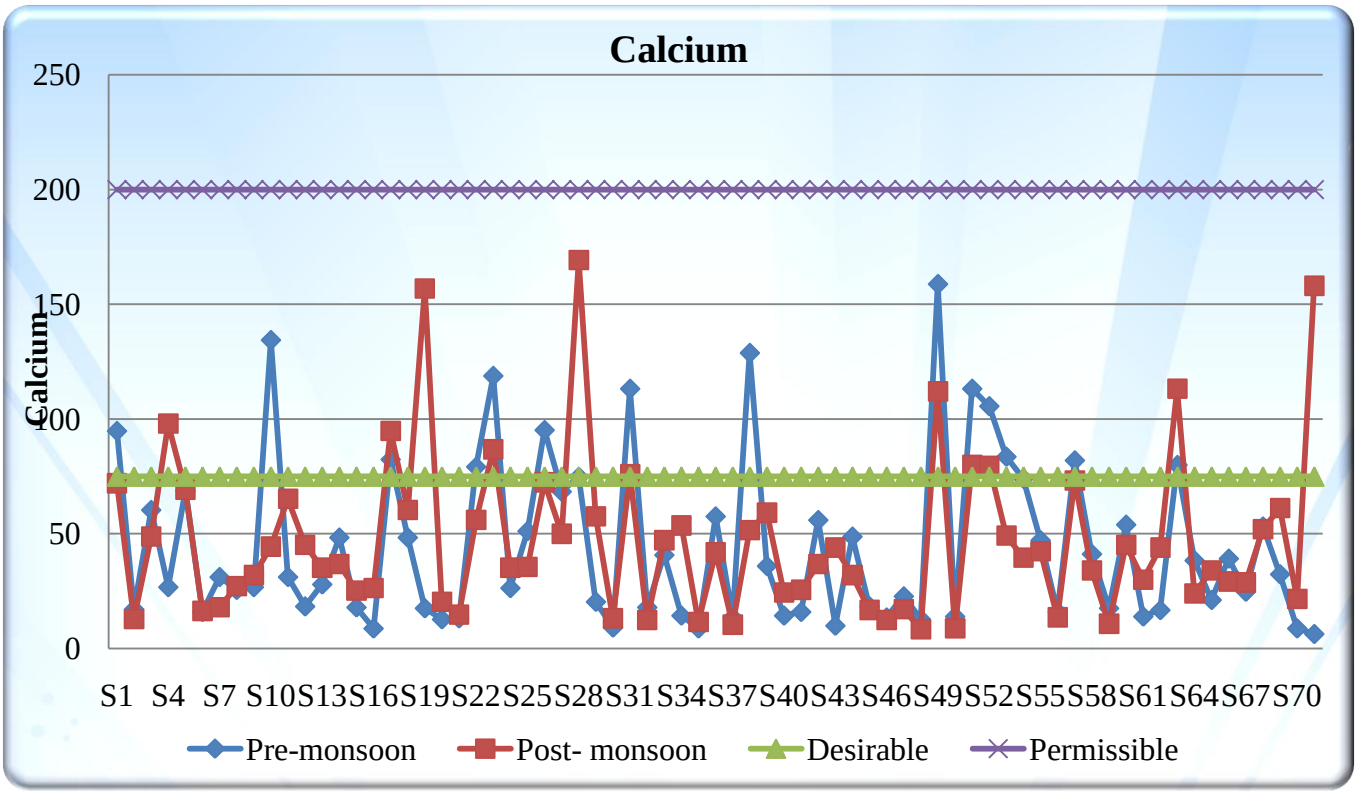

Figure 4: Spatial variation of Calcium in Pre and Post monsoon seasons

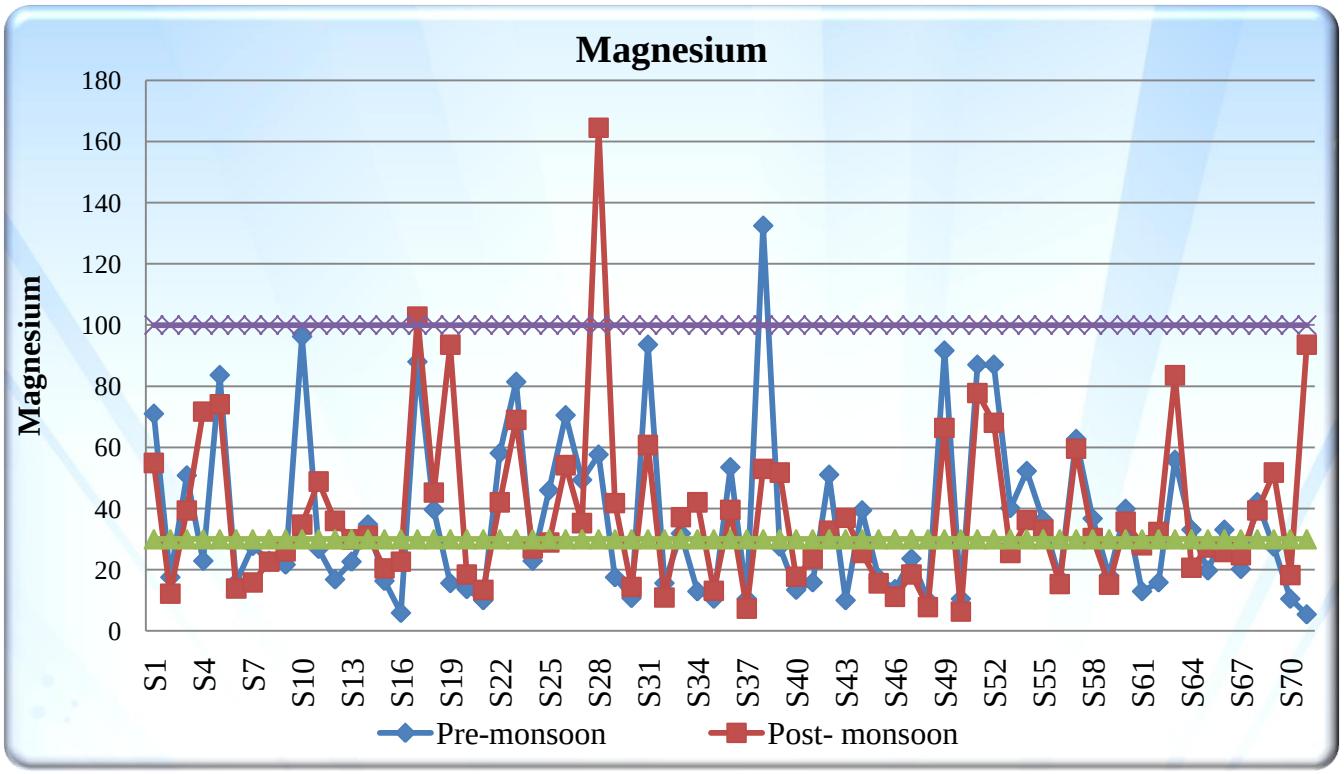

Figure 5: Spatial variation of Magnesium in Pre and Post monsoon seasons

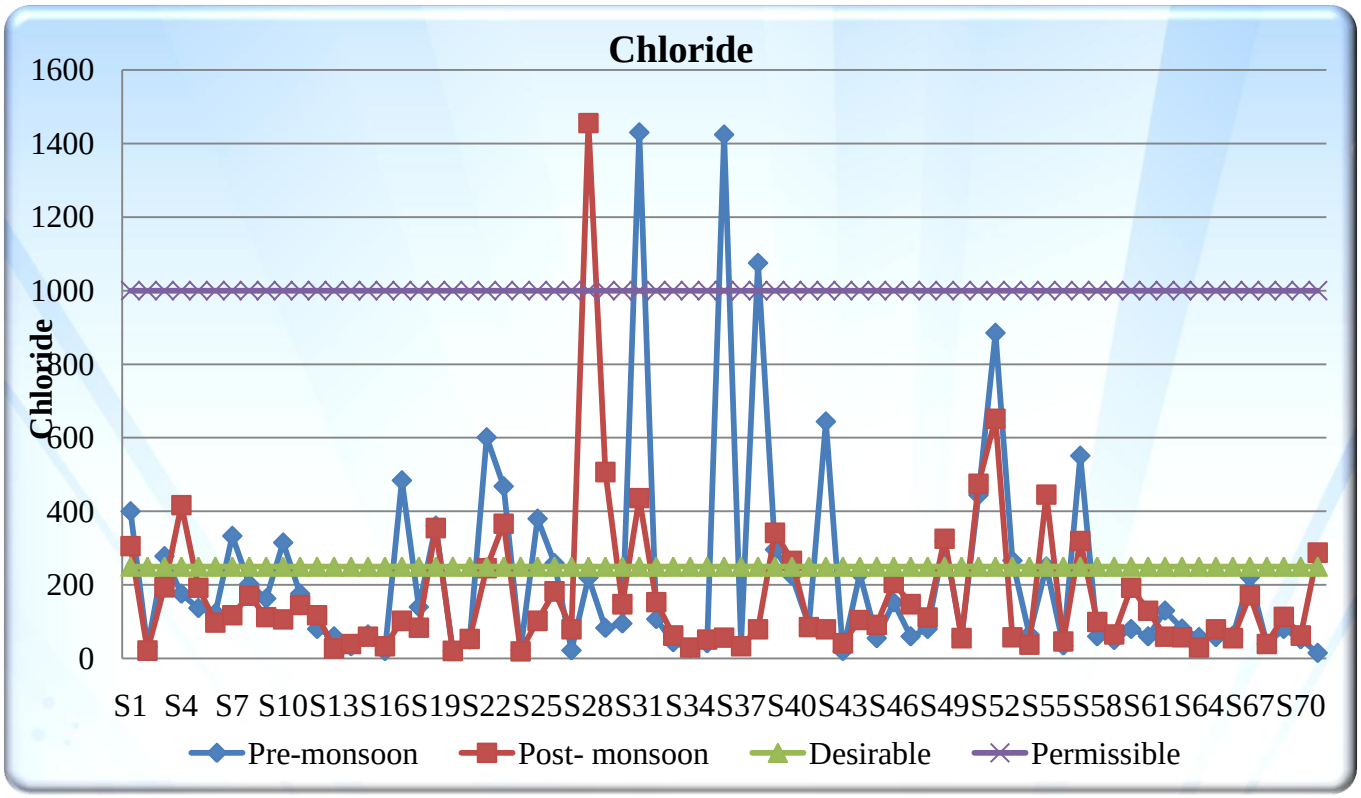

Figure 6: Spatial variation of Chloride in Pre and Post monsoon seasons

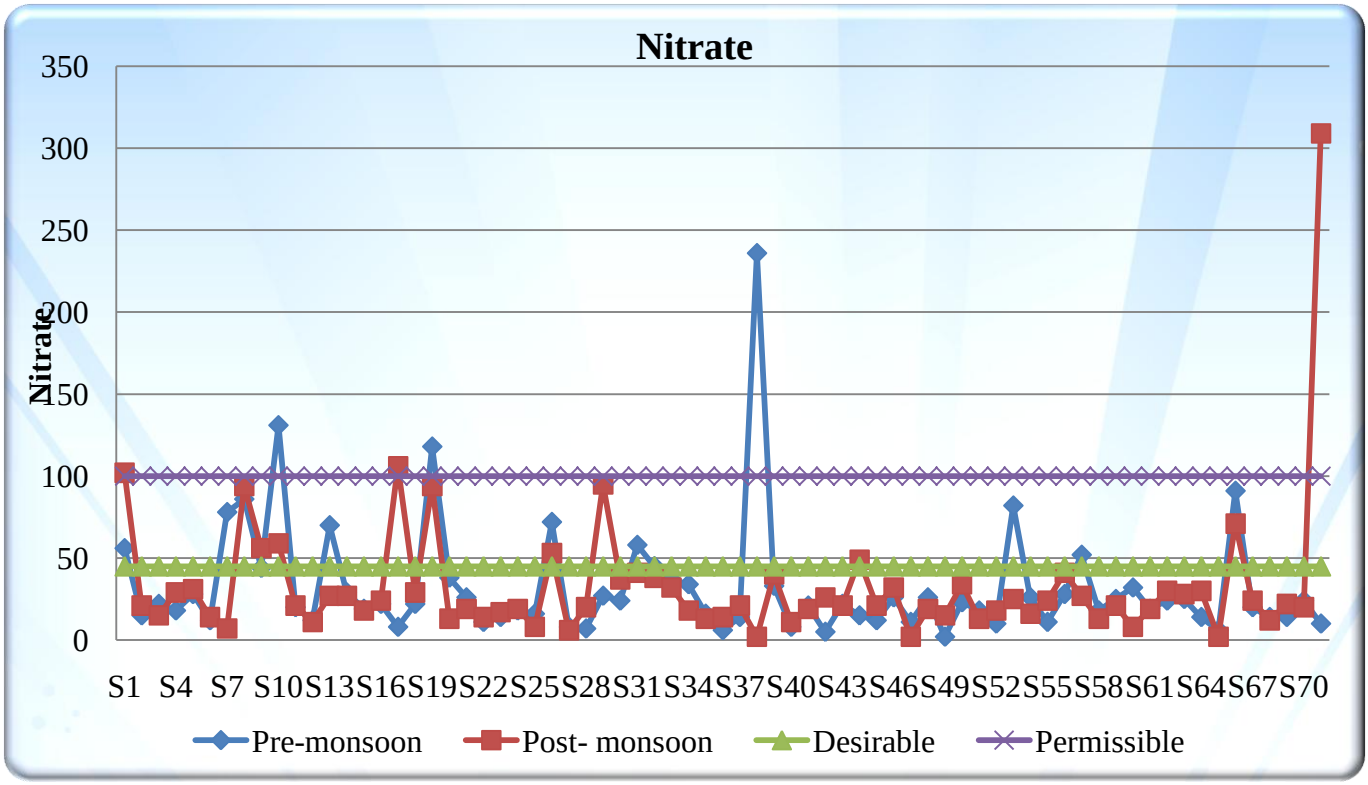

Figure 7: Spatial variation of Nitrate in Pre and Post monsoon seasons

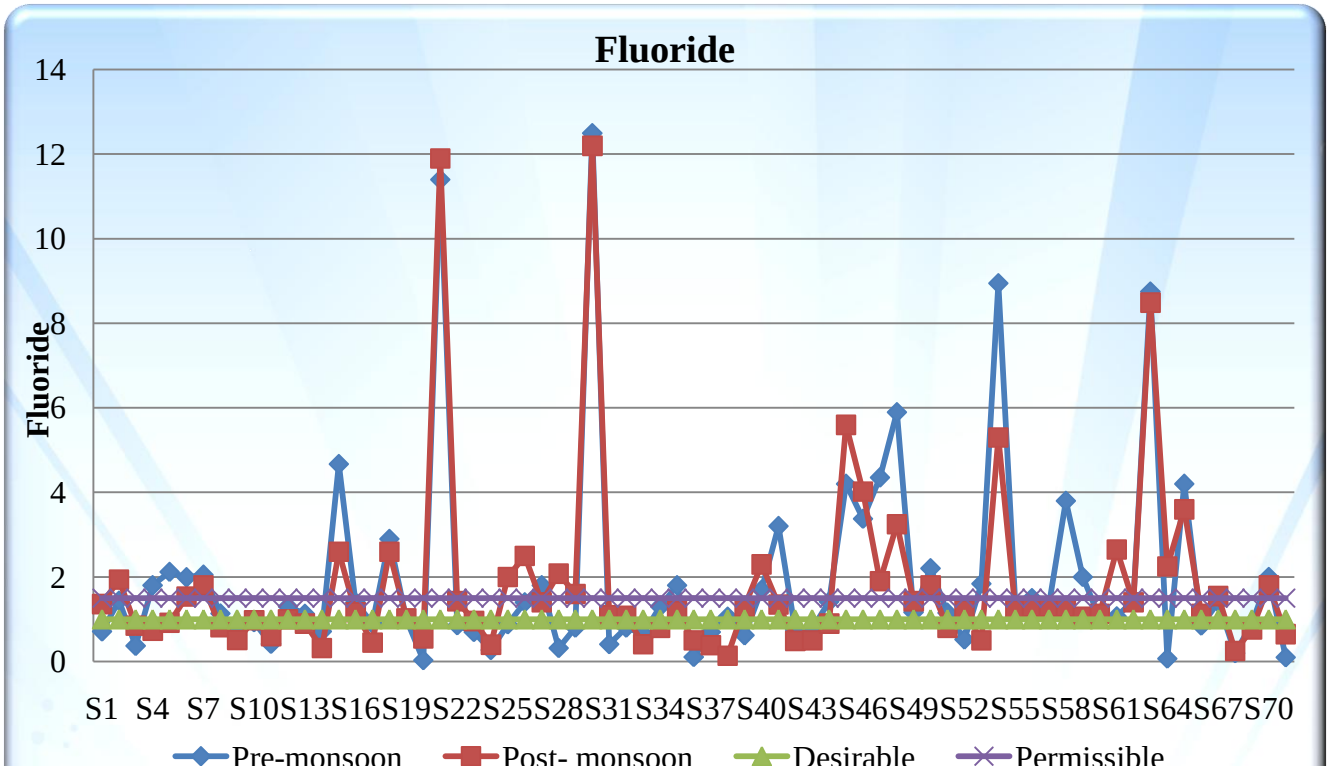

Figure 8: Spatial variation of Fluoride in Pre and Post monsoon seasons

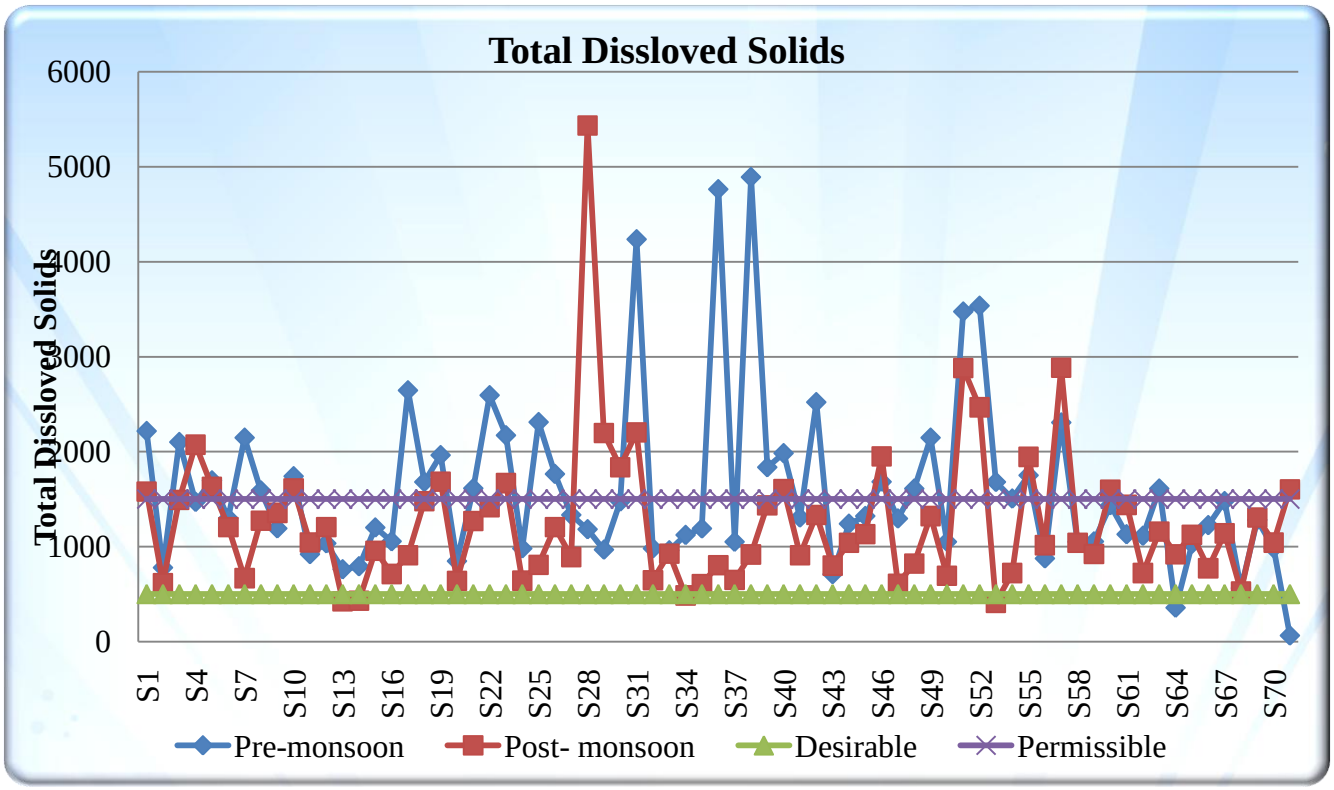

Figure 9: Spatial variation of Total Dissolved Solids in Pre and Post monsoon seasons

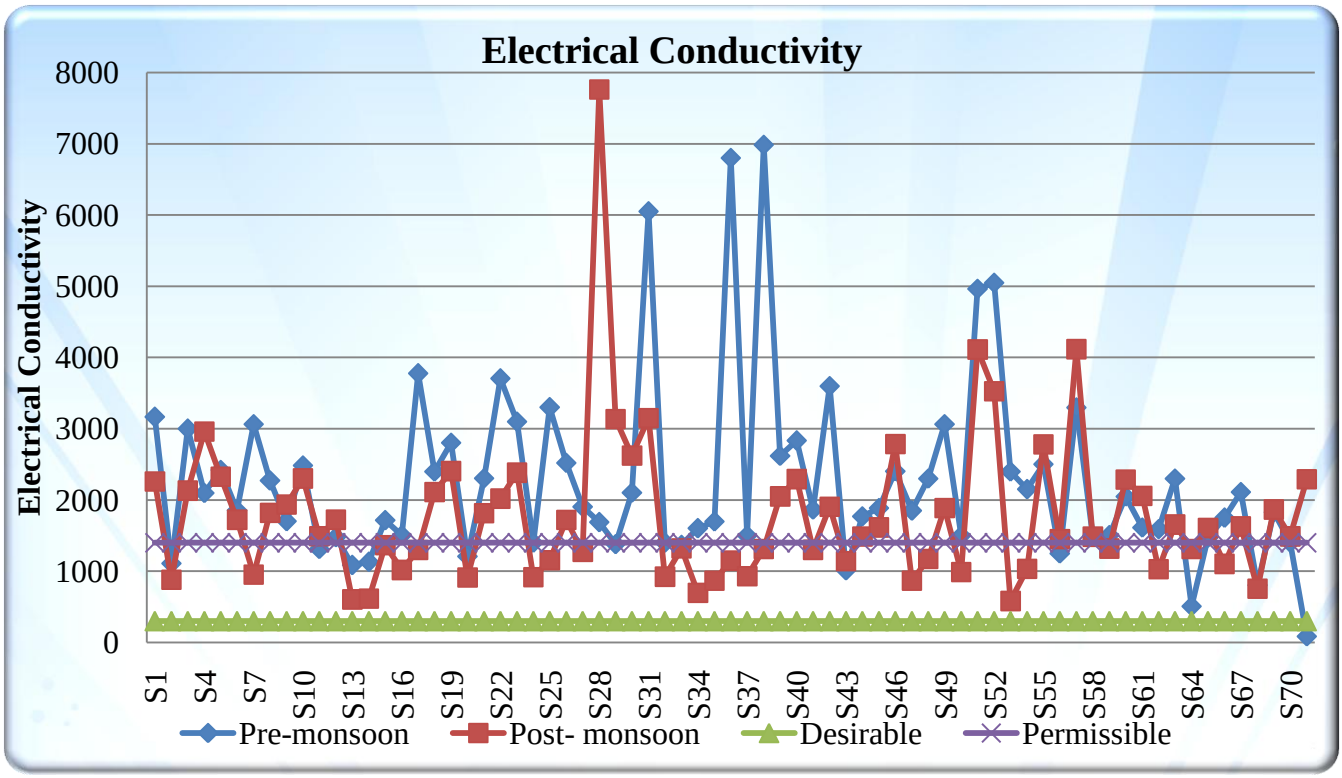

Figure 10: Spatial variation of Electrical Conductivity in Pre and Post monsoon season

A. *Seasonal Variation of Physico-chemical Parameters*

The seasonal variations of physico-chemical characteristics of groundwater in the study area are discussed below and presented in Fig. 11 to 20. Statistical parameters of both seasons are depicted in table 4 and 5.

[1] pH: The range of pH is from 7.1 to 8.5 in pre-monsoon and 7.1 to 8.6 in post monsoon. Most of the stations in the study show alkaline tendency. In pre-monsoon there is no sample having the pH value more than the desirable level (6.5 to 8.5) mentioned by BIS and ICMR, while in post monsoon two samples (S2 and S32) are exhibiting pH values more than the desirable limit. In pre-monsoon average value is 7.86 and in post- monsoon it has reduced to 7.80. Higher pH may cause incrustation sediment deposit and difficulties in chlorination for disinfection of water.

[2] Total Alkalinity: In pre-monsoon total alkalinity ranged from 36 to 795 mg/L and 168 to 871 mg/L in post-monsoon. Average value in pre-monsoon is 469.48 mg/L while it has increased to 495.04 mg/L in post-monsoon. In pre-monsoon season 98.59% samples are found to have alkalinity values higher than the highest desirable value 120 mg/L stipulated by ICMR and WHO and in post-monsoon all samples are having alkalinity values more than the desirable limit. In ground water, most of the alkalinity is caused due to carbonates and bicarbonates.

[3] Total Hardness: The determined total hardness in all stations ranges from 38 to 867 mg/L during pre-monsoon having the average value 260.19 mg/L but in post-monsoon it ranges from 48 to 1100 mg/L and the average value has increased up to 276.27 mg/L. The hardness of the many stations in pre and post monsoon seasons are well above the standard level set by BIS and ICMR as 300 mg/L. The presence of calcium or magnesium salts is the main responsible factor for the hardness of water [17]. Based on the amount of hardness the usability of water for domestic, drinking and industrial purpose can also be determined [18].

[4] Calcium: Calcium in the sampling stations ranges from 6.4 to 158.8 mg/L during pre monsoon and 8.4 to 169.2 mg/L during post monsoon. The average calcium value in pre and post- monsoon season is 44.49 and 47.35 mg/L respectively. In many samples it falls above the standard value 75 mg/L depicted by BIS, ICMR and WHO. The higher value is mainly attributed due to the abundant availability of lime stone in the area. Consequently more solubility of calcium ions is present

Table 4: Minimum, Maximum and Average Characteristics of Groundwater Sampling Sites – Pre Monsoon

S. No.	Parameter	Minimum	Maximum	Average	Standard Deviation
1.	pH	7.1	8.5	7.86	0.39
2.	Total Alkalinity (mg/L)	36	795	469.47	162.55

3.	Total Harness (mg/L)	38	867	260.19	201.90
4.	Calcium Hardness (mg/L)	16	397	111.23	90.30
5.	Ca^{+2} Ions (mg/L)	6.4	158.8	44.49	36.12
6.	Magnesium Hardness (mg/L)	22	545	148.95	113.86
7.	Mg^{+2} Ions (mg/L)	5.34	132.43	36.19	27.66
8.	Chloride (mg/L)	15	1430	222.01	290.48
9.	Nitrate (mg/L)	2	236	32.16	35.64
10.	Fluoride (mg/L)	0.03	12.5	1.96	2.41
11.	TDS (mg/L)	63	4890	1589.88	899.48
12.	EC (µmhos/cm)	86	6985	2271.05	1285.04

[5] Magnesium: Magnesium in the sampling sites ranges from 5.34 mg/L to 132.43 mg/L in the pre monsoon and 6.31 to 164.51 mg/L in the post monsoon season having the average value 36.19 and 38.36 mg/L in pre and post monsoon season respectively. In both the seasons various samples are showing magnesium values higher than the highest desirable limit 30 mg/L (BIS, ICMR and WHO). The concentration of magnesium may be very high due to dissolution of magnesium, calcite, gypsum and dolomite [19].

Table 5: Minimum, Maximum and Average Characteristics of Groundwater Sampling Sites – Post Monsoon

S. No.	Parameter	Minimum	Maximum	Average	Standard Deviation
1.	pH	7.1	8.6	7.80	0.31
2.	Total Alkalinity (mg/L)	168	871	495.04	174.15
3.	Total Harness (mg/L)	48	1100	276.26	195.79
4.	Calcium Hardness (mg/L)	21	423	118.38	87.05
5.	Ca^{+2} Ions (mg/L)	8.4	169.2	47.35	34.82
6.	Magnesium Hardness (mg/L)	26	677	157.88	111.31
7.	Mg^{+2} Ions (mg/L)	6.31	164.51	38.36	27.05
8.	Chloride (mg/L)	20	1455	171.04	206.72
9.	Nitrate (mg/L)	2	309	32.77	40.60
10.	Fluoride (mg/L)	0.14	12.2	1.82	2.20
11.	TDS (mg/L)	408	5434	1252.28	746.36
12.	EC (µmhos/cm)	583	7763	1788.87	1066.23

[6] Chloride: The chloride values are 15 to 1430 mg/L in Pre monsoon season and 20 to 1455 mg/L in Post monsoon. In pre-monsoon the average value is 222.01 mg/L while in post-monsoon it is 171.04 mg/L. Chloride concentration in most of the sample were found higher than highest desirable level (250 mg/L) stipulated by BIS and ICMR, yet these values are well below the maximum permissible limit (1000 mg/L) but still there are some samples exhibiting the values more than the maximum permissible limit. Excess of chloride is due to anthropogenic activity like septic tanks effluents, usage of bleaching agents by people nearby bore well.

[7] Nitrate: Nitrate concentrations in the study area ranged from 2.0 to 236 mg/L in the pre monsoon having the average value 32.16 mg/L and 2.0 to 309 mg/L in post monsoon season with the average value 32.77 mg/L. In both seasons various samples are found to have nitrate values more than the desirable limit of 45 mg/L (BIS, ICMR and WHO). The nitrate contamination in ground water is due to the leaching of nitrate present on the surface with percolating water and in presence of its high concentration drinking water becomes toxic [20].

[8] Fluoride: Fluoride concentration in the sampling sites ranges from 0.03 mg/L to 12.5 mg/L in pre monsoon and 0.14 to 12.2 mg/L in post monsoon seasons having the average value 1.97 and 1.82 mg/L respectively in both seasons. Most of the samples are having fluoride concentration more than the permissible limit 1.5 mg/L (BIS, ICMR and WHO) and suffering from the acute fluoride problems. Groundwater usually contains fluoride dissolved by geological formations. According to Central Ground Water Board (CGWB), the aquifers in this area are mainly composed of quartzite, schist and phyllite minerals.

[9]Total Dissolved Solids: The range of total dissolved solids is from 63 to 4890 mg/L during pre monsoon and it is 408 to 5434 mg/L in the post monsoon. The average value is 1589.88 mg/L in pre monsoon and 1252.28 mg/L in post monsoon. This shows that, most of the stations fall above standard level 500 mg/L stipulated by BIS, ICMR and WHO, showing the anthropogenic impact which can be due to agricultural activity leading to local spatial and temporal variability of runoff [21].

[10] Electrical Conductivity: The value of electrical conductivity lies between 86-6985 µmhos/cm and 583-7763 µmhos/cm and average values are 2271.05 µmhos/cm and 1788.87 µmhos/cm in pre and post monsoon seasons respectively. The concentration of ions, nutrient status and variation of dissolved solid content are the main contributing factors to the amount of electrical conductivity. Based on electrical conductivity values the water quality can be categorized as poor, medium or good [22]. In our findings, almost all samples are showing the EC values more than the desirable limit 300 mg/L given by ICMR and WHO.

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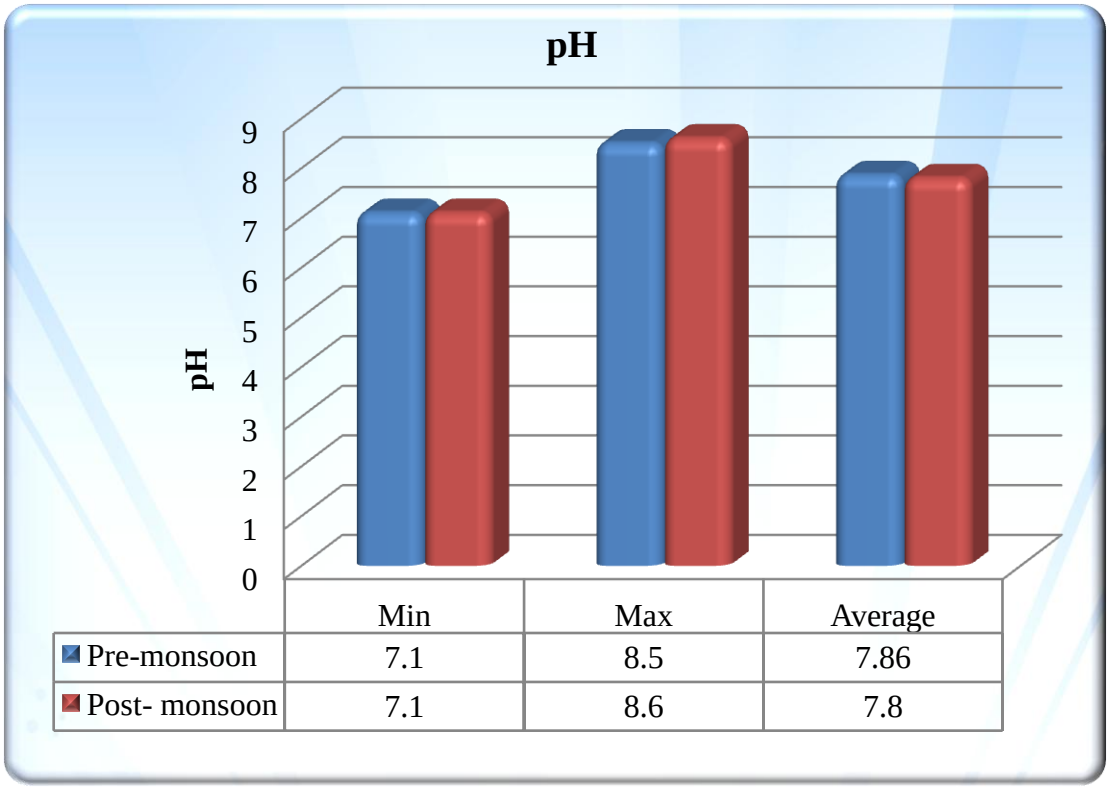

Figure 11: Seasonal variation of pH in the study area

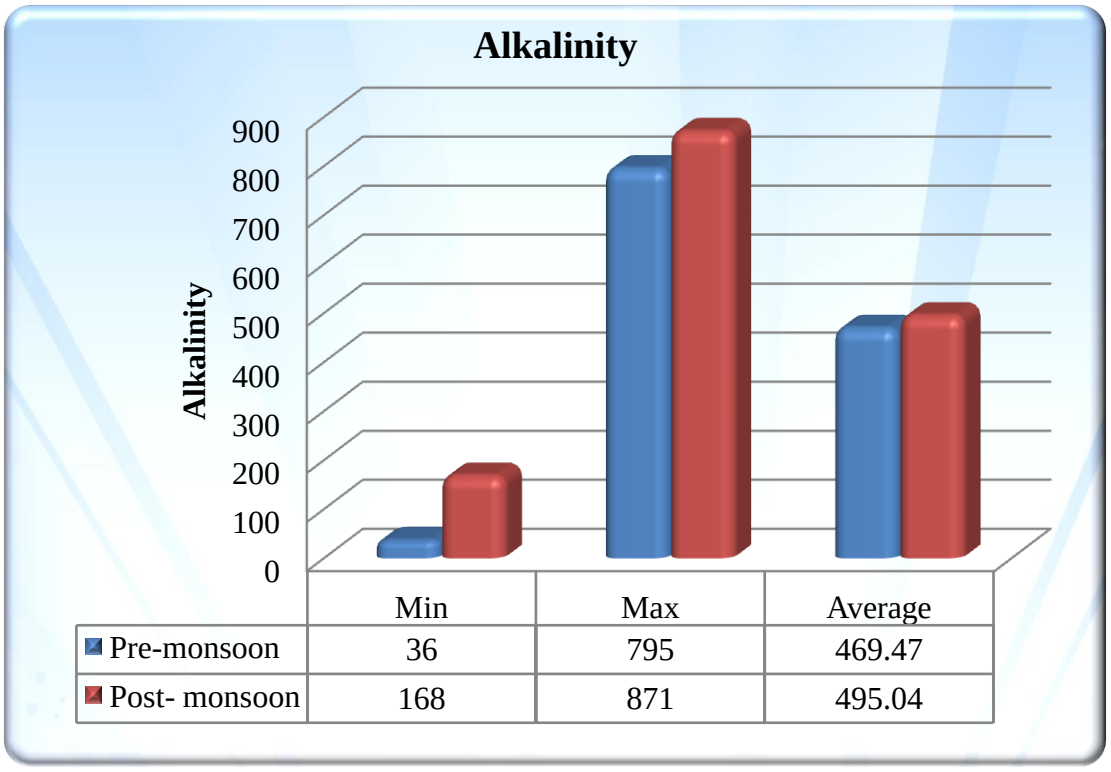

Figure 12: Seasonal variation of Total Alkalinity in the study area

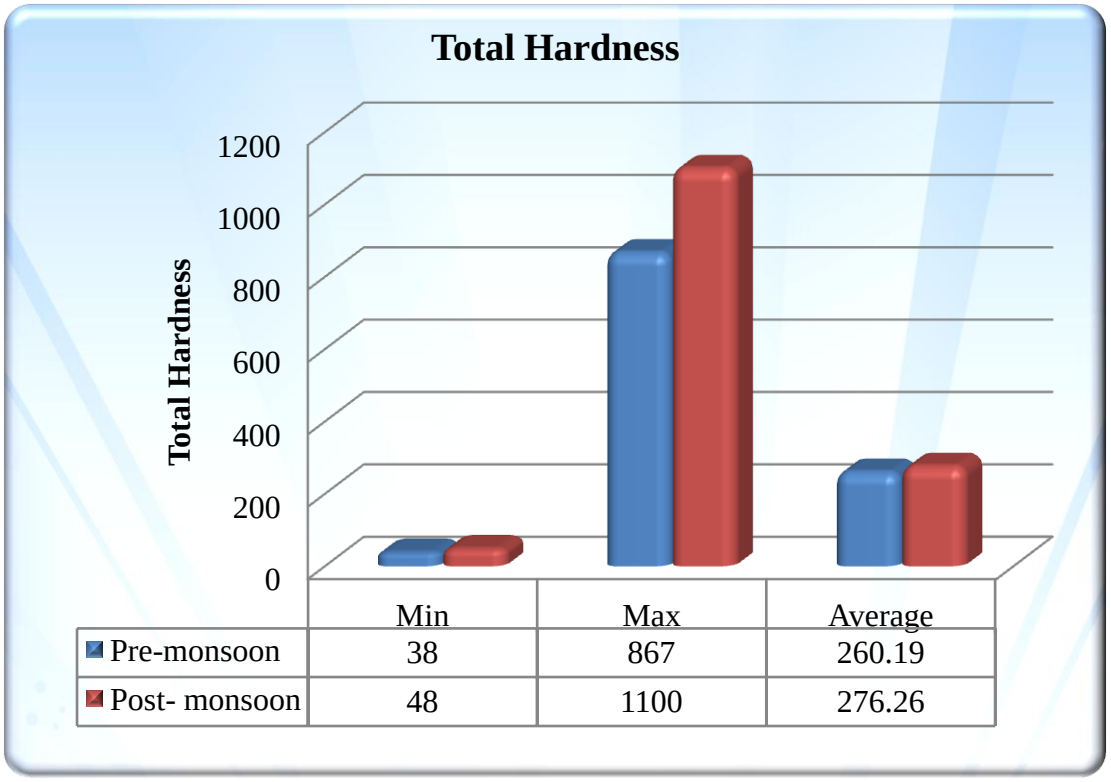

Figure 13: Seasonal variation of Total Hardness in the study area

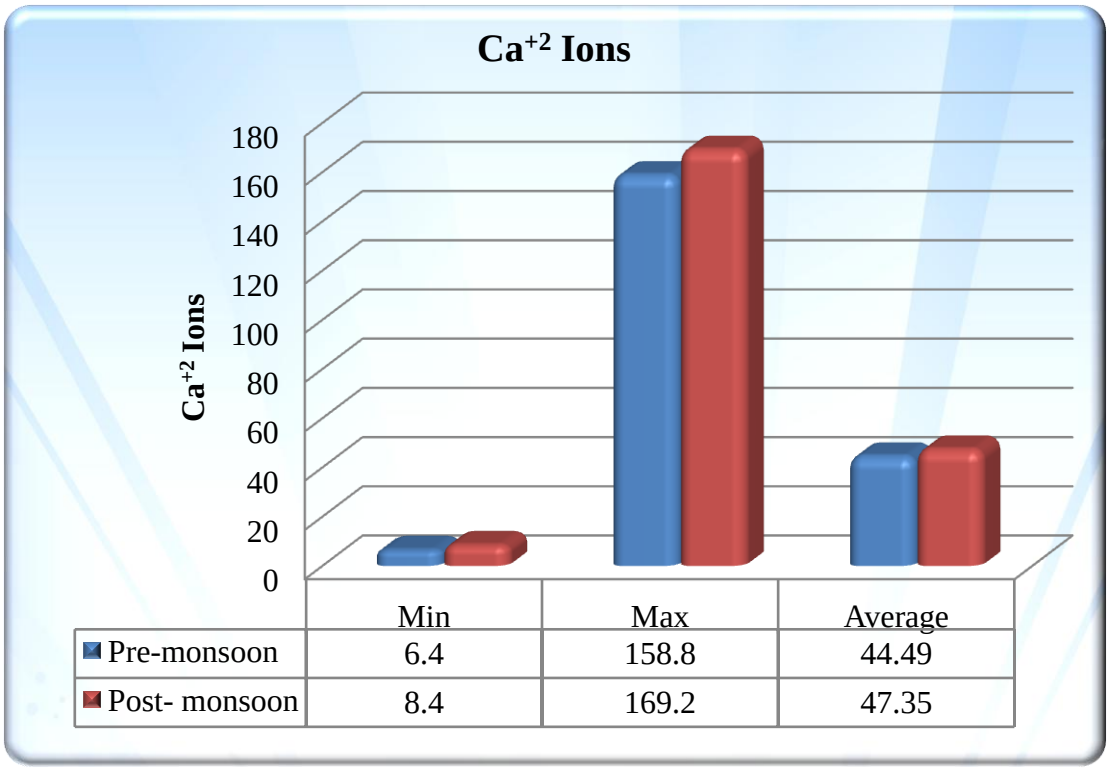

Figure 14: Seasonal variation of Calcium in the study area

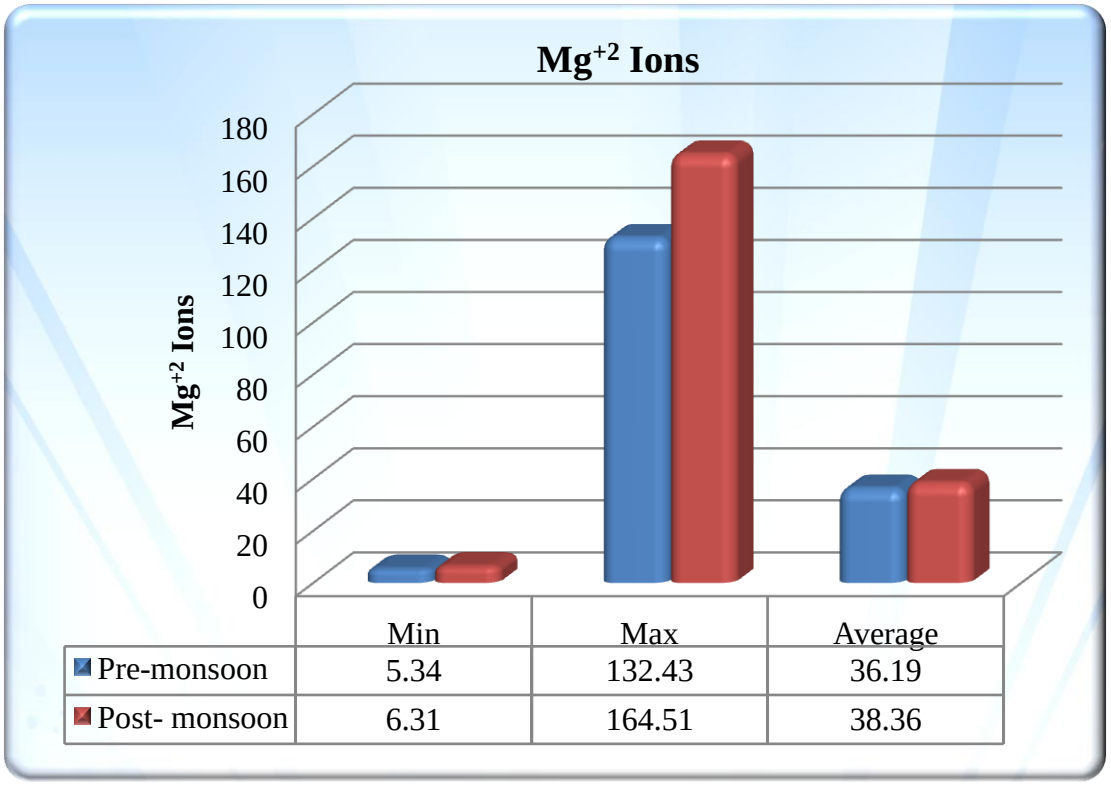

Figure 15: Seasonal variation of Magnesium in the study area

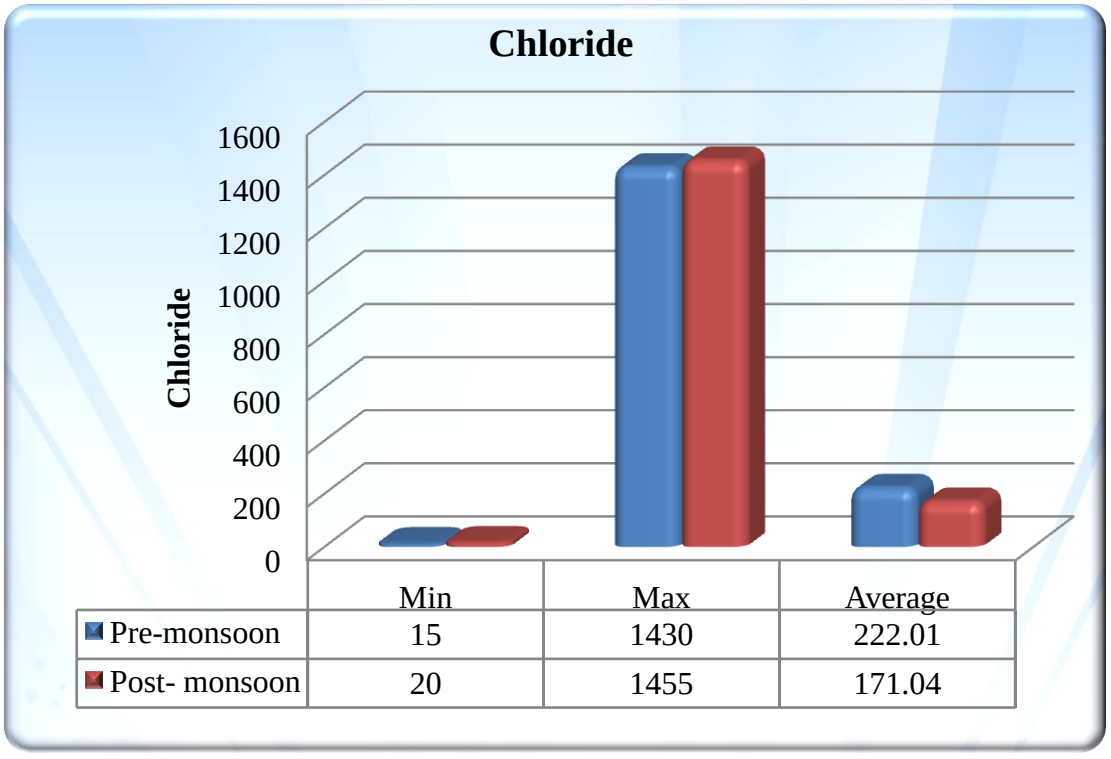

Figure 16: Seasonal variation of Chlorides in the study area

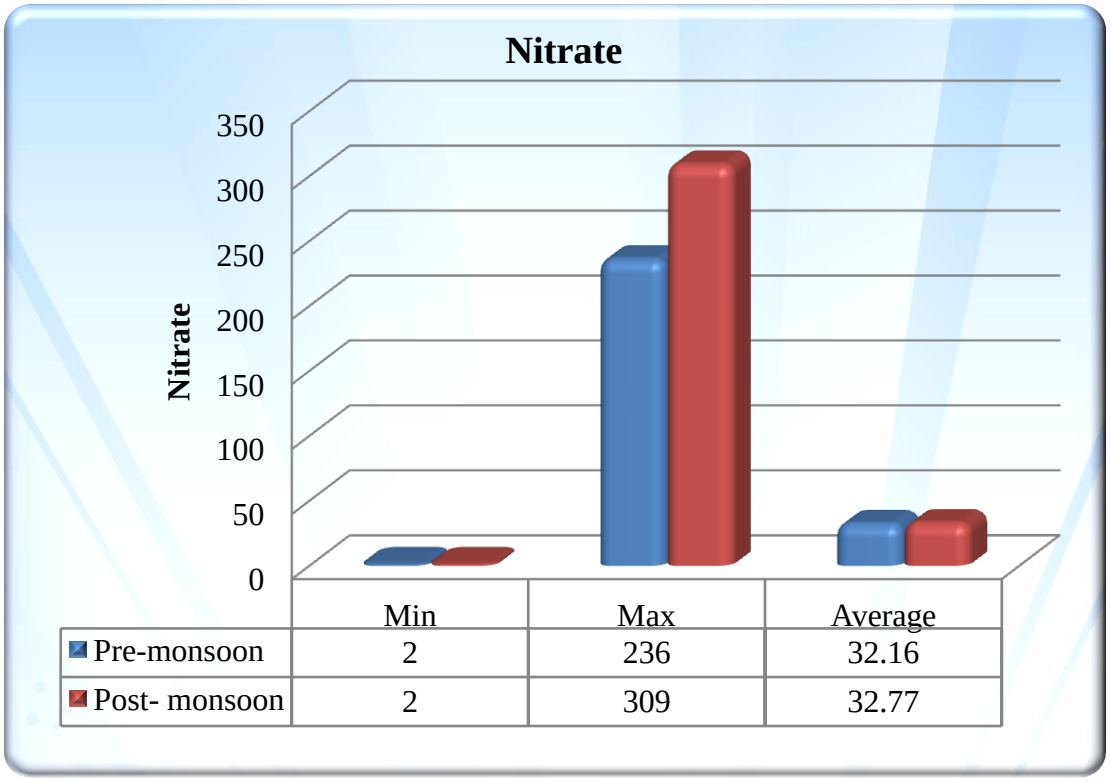

Figure 17: Seasonal variation of Nitrates in the study area

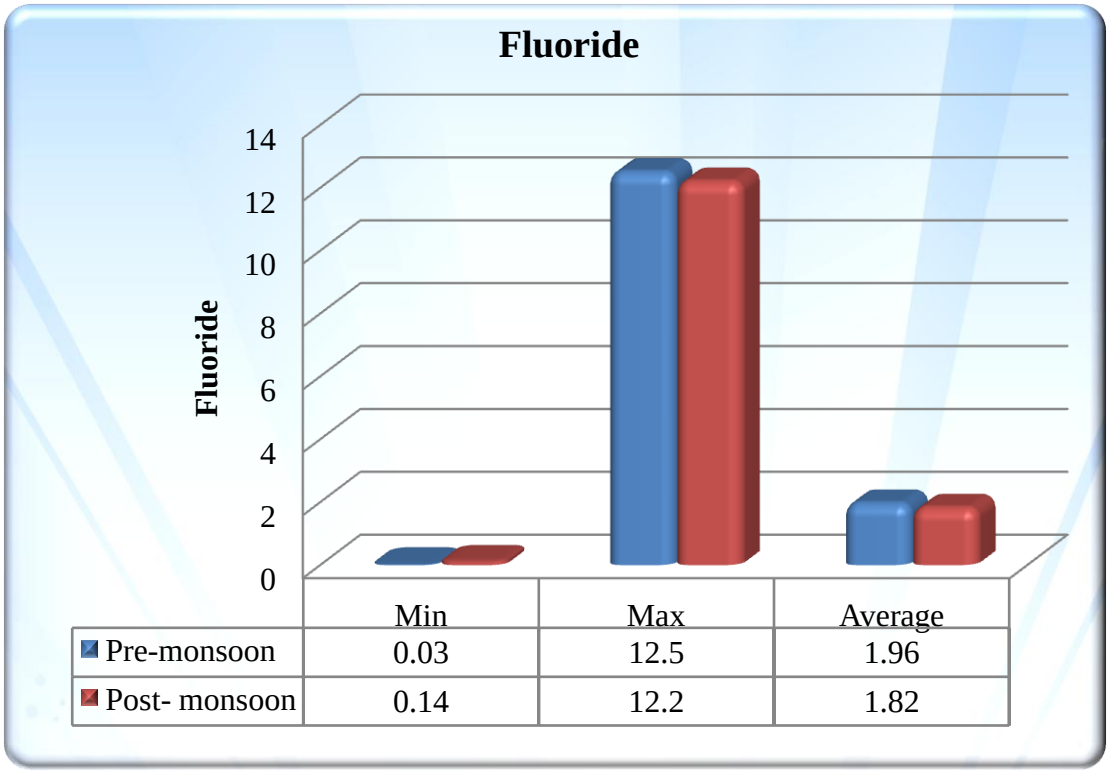

Figure 18: Seasonal variation of Fluorides in the study area

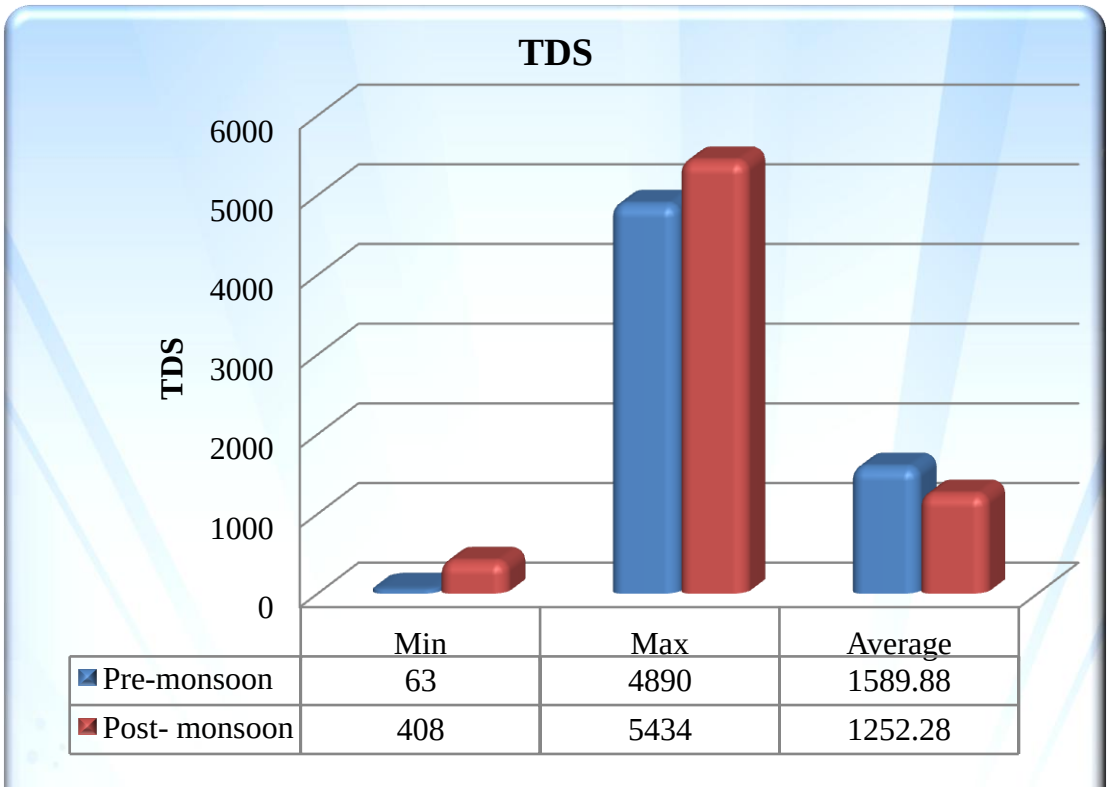

Figure 19: Seasonal variation of Total Dissolved Solids in the study area

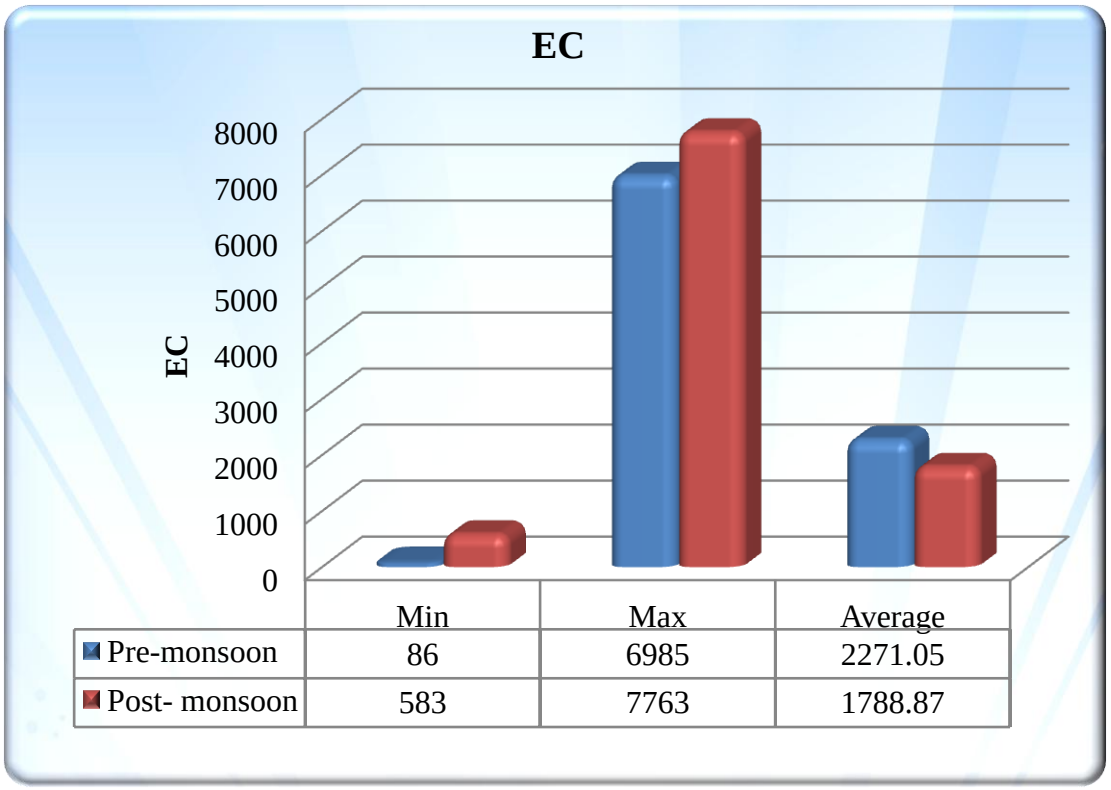

Figure 20: Seasonal variation of Electrical Conductivity in the study area

IV. CONCLUSIONS

In the present study, from analysis of pre and post monsoon data it can be inferred that almost all parameters are exhibiting values higher than the permissible limits. At some sampling sites values are increasing in post monsoon and at some sites these are decreasing in post monsoon, but we cannot define any certain pattern in these increasing or decreasing trends. TDS and EC mostly exhibits decrease in values while in some samples they also found to have increased values. The reason can be attributed to increase in concentration as a result of greater leaching and decrease in concentration as a result of dilution.

In the entire study only one ground water sample S71 in village *Tunga* in pre monsoon season have all values of physico–chemical parameters within the permissible limits. In pre monsoon season all groundwater samples have pH value under the permissible limit whereas in post monsoon season two samples have higher pH value. Total alkalinity, Total dissolved solids and Electrical conductivity values are higher than the permissible limits in almost all groundwater samples in both seasons.

The final output given in the spatial representation graphs of groundwater quality in the study area indicates that the groundwater of the study area necessarily needs some treatment before consumption. The study also helps to understand the quality of water as well as to develop suitable management practices to protect the groundwater sources.

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