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Research article

CORRELATION AND REGRESSION ANALYSIS OF GROUND WATER OF BASSI TEHSIL, DISTRICT JAIPUR, RAJASTHAN, INDIA

Swati Saxena[1] and Umesh Saxena[2*]

[1]Research Scholar, Department of Chemistry, Suresh Gyan Vihar University, Jaipur, Rajasthan (India).
[2]Principal and Professor, Department of Chemistry and Environmental Science, Chanakya Technical Campus, Jaipur, Rajasthan, (India)

ABSTRACT: The present study deals with statistical analysis of Physico-chemical parameters of ground water quality in Bassi Tehsil of District Jaipur, Rajasthan, India. 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 permissible limits prescribed by BIS, ICMR and WHO. The quality of ground water has been assessed by calculating correlation coefficient (r) for every pair of parameters. Regression equations were also being formulated for pairs having highly significant ($0.8<r<1.0$) and moderately significant ($0.6<r<0.8$) correlation coefficients. Comparison has been made between the observed value and the predicted value to observe water quality and percentage error (%e) has also been calculated followed by drawing scatter plots. To analyze the relevance and utility of applied regression model R, R^2 and adjusted R^2 values were determined and significance of the regression model was indicated by p-value. A systematic correlation and regression study depicted linear relationship among different water quality parameters. The analysis provides an easy and rapid way to estimate as well as to monitor the water quality.

Key Words: Water Quality, Physico-chemical parameters, Statistical Parameters, Correlation Coefficient, Regression Analysis.

Abbreviations: TA- Total Alkalinity, TH- Total Hardness, Ca H- Calcium Hardness, Mg H- Magnesium Hardness, TDS- Total Dissolved Solid, EC- Electrical Conductivity, mg/L- milligram per liter.

*Corresponding author: Umesh Saxena, Department of Chemistry and Environmental Science, Chanakya Technical Campus, Jaipur, Rajasthan, India, E-mail: saxenaumesh@yahoo.com Phone No.: +91-141-2293128

INTRODUCTION

Water is the elixir for life. It is the most vital resource for the existence of life on earth. No other natural resource has had such an overwhelming influence on human history. In early time's habitation used to be near rivers, lakes and springs, without water there would have been no life. But at present this most precious resource is getting deteriorated. Potable safe water is absolutely essential and is the basic need of all human beings on the earth. Due to modern civilization, rapid urbanization, and industrialization, subsequent contamination of surface and ground water sources, water conservation and water quality management has now a day's assumed a very complex shape. Attention on contamination and its management has become a need of the hour, because of its far reaching impact on human health.

Statistical investigation offers more attractive options in environment science, though the result may deviate more from real situations [1]. The correlation provides an excellent tool for the prediction of parametric values within a reasonable degree of accuracy [2]. The quality of water is described by its physical, chemical and microbial characteristics. But, if some correlations are possible among these parameters, then the more significant ones would be useful to indicate fairly the quality of water [3]. A systematic study of correlation and regression coefficients of the water quality parameters not only helps to assess the overall water quality but also to quantify relative concentration of various pollutants in water and provide necessary cue for implementation of rapid water quality management programmes. The developed regression equations for the parameters having significant correlation coefficients can be successfully used to estimate the concentration of other constituents [4, 5, 6, 7 and 8].

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 no studies have been made to scientifically investigate the ground water contamination of the study area. The present study aims to analyse correlation and regression study of various 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.

MATERIALS AND METHODS

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.

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.

Calculation of Statistical Parameters

In the present study Minimum, Maximum, Average, Standard Deviation, Correlation coefficient (r) and regression coefficients (a & b) has been calculated for each pair of water quality parameters by using Excel spreadsheet for the experimental data.

The standard formulae were used in the calculation for statistical parameters are as follows [6, 17]:

$$Mean\ (\mu) = \frac{\sum x}{N}$$

x = Values of Parameter
N = Number of Observations

$$Standard\ Deviation\ (\sigma) = \sqrt{\frac{n\sum x^2 - (\sum x)^2}{n\ (n-1)}}$$

x = Values of Parameter
n = Number of Observations

Correlation coefficients [PEARSON] (r) have been calculated between each pair of water quality parameter for the experimental data. Let x and y be the two variables, then the correlation 'r' between the two variables are given by-

$$Karl\ Pearson's\ Coefficient\ of\ Correlation\ r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\ \sum x^2 - (\sum x)^2}\sqrt{n\sum y^2 - (\sum y)^2}}$$

n = Number of Observations
The linear regression equation **y = ax+b** was developed for the pairs having highly significant ($0.8 < r < 1.0$) and moderate significant ($0.6 < r < 0.8$) 'r' values [6, 8].

Where, *y* = Dependent variable
x = Independent variable
a = Slope of line
b = Intercept on *y* – axis
'a' and 'b' can be calculated with the help of following equations- [7].

$$\mathbf{a} = \frac{n(x\ y) - x\ y}{n(x^2) - (x)^2}$$

$$\mathbf{b} = \frac{y - a\ x}{n}$$

The regression analysis is carried out by taking one parameter as dependent variable and other parameter as independent variable. Regression equation is developed with the assumption that change in dependent parameter (*y*) is either directly or indirectly proportional to the change in the independent parameter [4, 5]. *R* value tells us how strongly the independent variable is related to the dependent variable. R^2 values indicate how much of the dependent variable can be explained by the independent variable and Adjusted R^2 has a number of properties which makes it a more desirable goodness –of – fit measure than R^2. Significant column indicates the statistical significance of the regression model that is applied. It is denoted by *p* value; if it is under 0.05 then the variable is significant.

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	Spectrophotometer
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

RESULT AND DISCUSSION

Physico-chemical Parameters

The respective values of all observed water quality parameters of groundwater samples in pre and post monsoon seasons are illustrated in Table-2 and 4 respectively. Statistical Parameters of groundwater samples of study area in both seasons are summarized in Table-3 and 5.

Correlation Analysis

In the present study the correlation coefficients (r) among various water quality parameters have been calculated and the numerical values of correlation coefficients (r) are tabulated in Table-6 and 7.Correlation coefficient (r) between any two parameters, x & y is calculated for parameter such as water pH, total alkalinity, total hardness, calcium, magnesium, chloride, nitrate, fluoride, total dissolved solids and electrical conductivity of the ground water samples. The degree of line association between any two of the water quality parameters as measured by the simple correlation coefficient (r) is presented as 10 x 10 correlation matrix.

Positive correlation is obtained between 39 combinations (70.90% of the total number) and rest 16 combinations (29.09%) exhibit negative correlation in both pre and post monsoon seasons. In pre monsoon season pH has been found to show positive correlation with total alkalinity and fluoride and negative correlations with total hardness, calcium, magnesium, chloride, nitrate, total dissolved solids and electrical conductivity. EC has negative correlation with pH and fluoride while all other parameters are positively correlated with EC. Out of the 55 correlation coefficients, 6 correlation coefficients (r) between the Calcium-TH (0.9861), Magnesium-TH (0.9912), Mg^{+2} -Ca^{+2} (0.9555), TDS-Cl^{-} (0.9130), EC- Cl^{-} (0.9129) and EC-TDS (0.9999) are observed with highly significant levels (0.8< r < 1.0). High positive correlation of TDS and Cl^{-} with EC indicates the high mobility of ions, while high correlation of total hardness with Ca^{+2} and Mg^{+2} exhibits that hardness is mainly due to presence of Ca^{+2} and Mg^{+2} salts in water.8 correlation coefficients gives the moderate significant (0.6< r < 0.8) level of 'r' values and there is only one value of 'r' which belongs to the significant coefficient levels (0.5< r < 0.6) Cl^{-} - Ca^{+2} (0.5932).

In post monsoon season, EC Shows negative correlation only with pH and with all rest parameters it has positive correlation, in pre monsoon it was having negative correlation with Fluoride. Fluoride is indicating positive correlation with only 4 parameters namely pH, TA, TDS and EC while nitrate is representing negative correlation with pH and TA, just opposite to the nature of fluoride. Out of the 55 correlation coefficients, 6 correlation coefficients (r) between the Calcium-TH (0.9833), Magnesium-TH (0.9898), Mg^{+2} -Ca^{+2} (0.9475), TDS-Cl^{-} (0.9116), EC- Cl^{-} (0.9116) and EC-TDS (0.9999) are observed with highly significant levels (0.8< r < 1.0). These values also provide the same conclusion, drawn in pre monsoon season. 7 values of the correlation coefficient (r) fall in the category of moderate significant levels (0.6< r < 0.8) and 2 value between TDS-Ca^{+2} and EC-Ca^{+2} are classified under the significant levels of correlation coefficient (0.5< r < 0.6). Scatter diagrams for highly significant positive correlations in pre and post monsoon seasons are depicted in Figure-1 to 12.

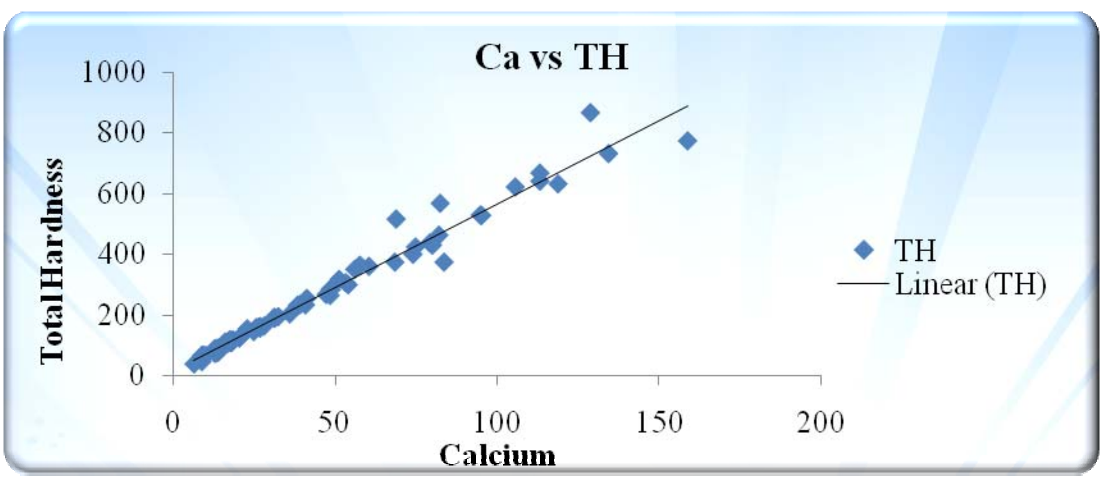

Figure 1: Correlation between Calcium and Total Hardness in Pre Monsoon Season

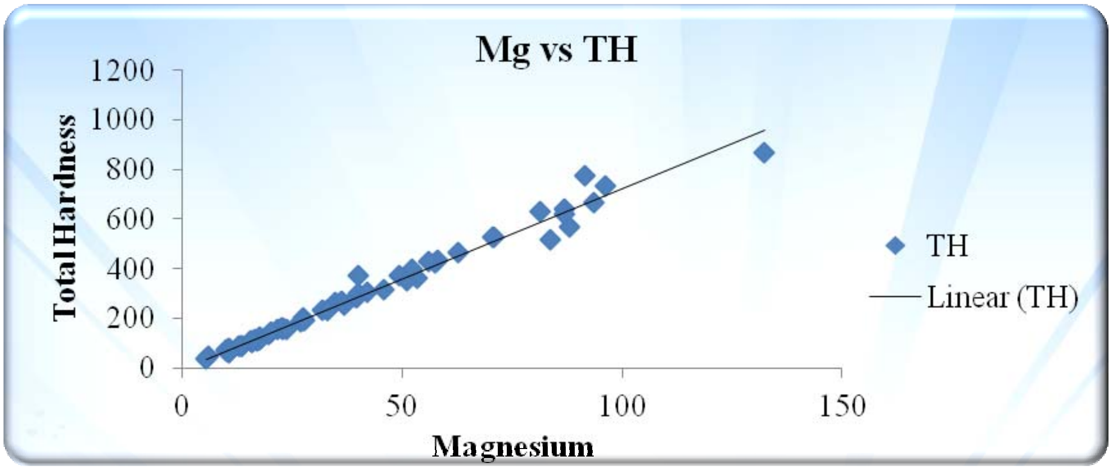

Figure 2: Correlation between Magnesium and Total Hardness in Pre Monsoon Season

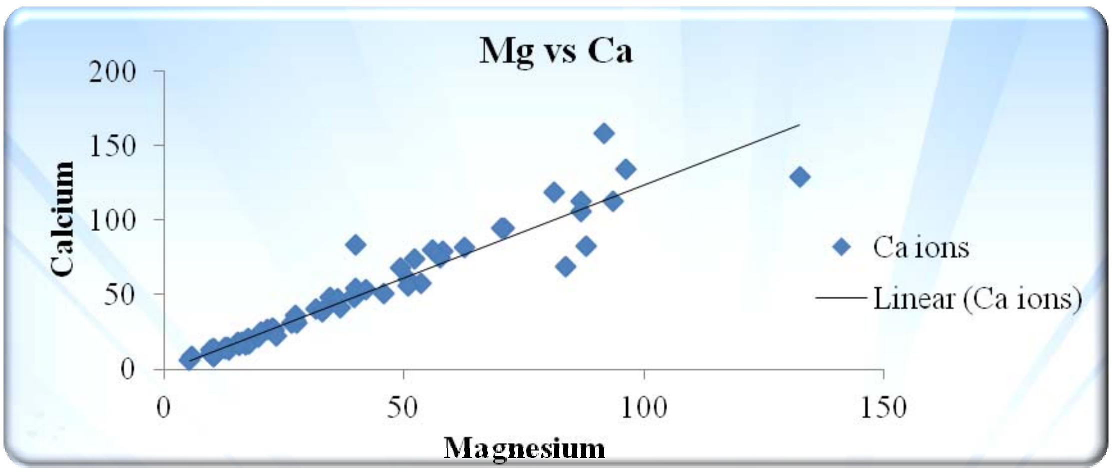

Figure 3: Correlation between Magnesium and Calcium in Pre Monsoon Season

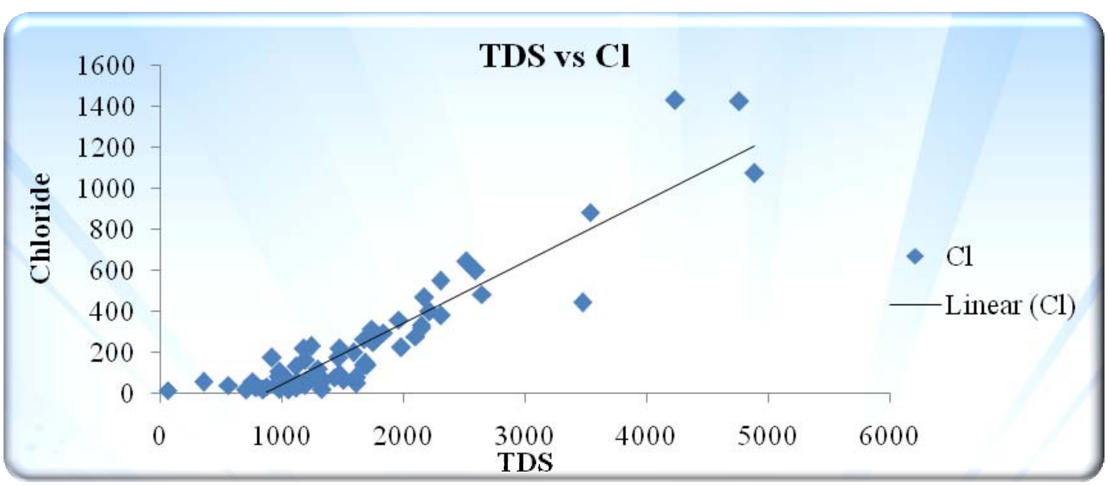

Figure 4: Correlation between TDS and Chloride in Pre Monsoon Season

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
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
		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 $CaCO_3$)

Table 3: Minimum, Maximum and Average Characteristics of Groundwater Sampling Stations – Pre Monsoon Season

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

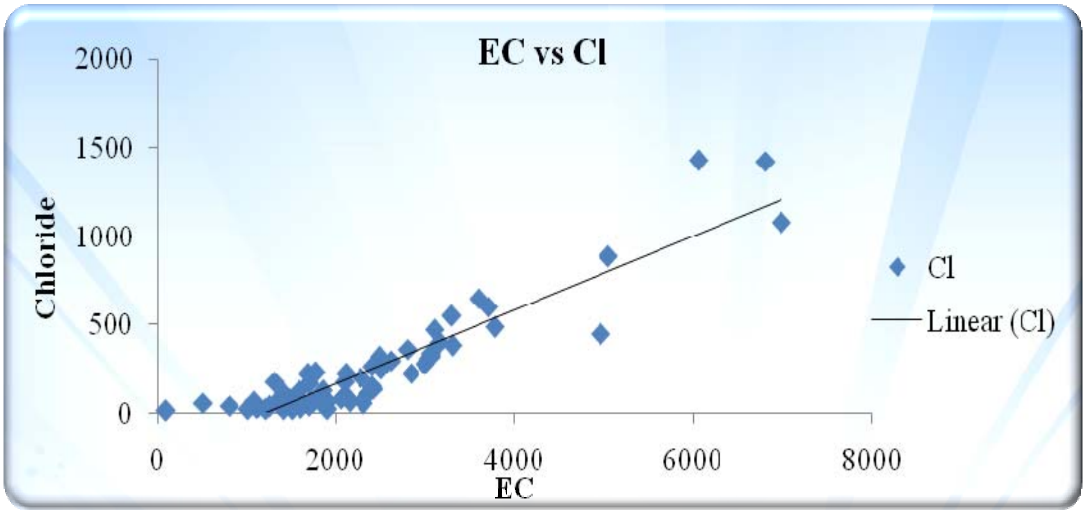

Figure 5: Correlation between EC and Chloride in Pre Monsoon Season

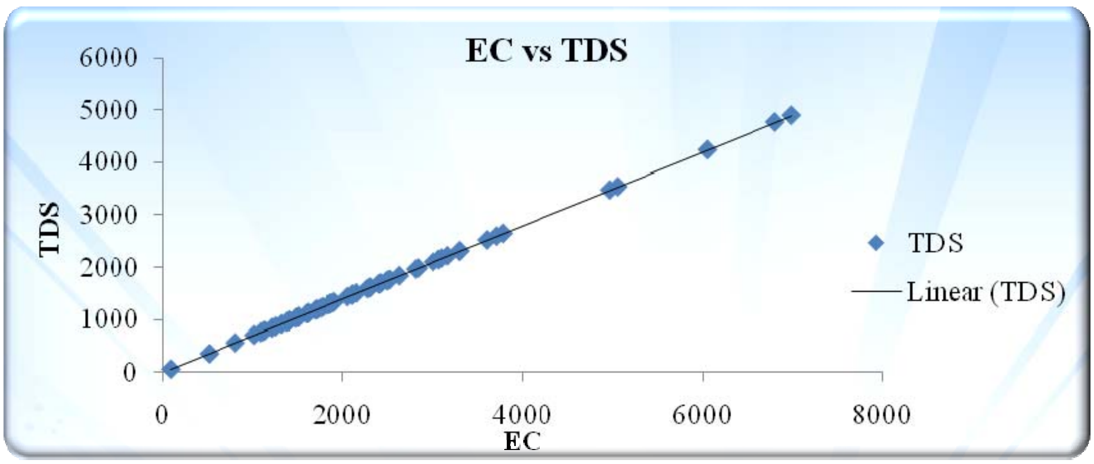

Figure 6: Correlation between EC and TDS in Pre Monsoon Season

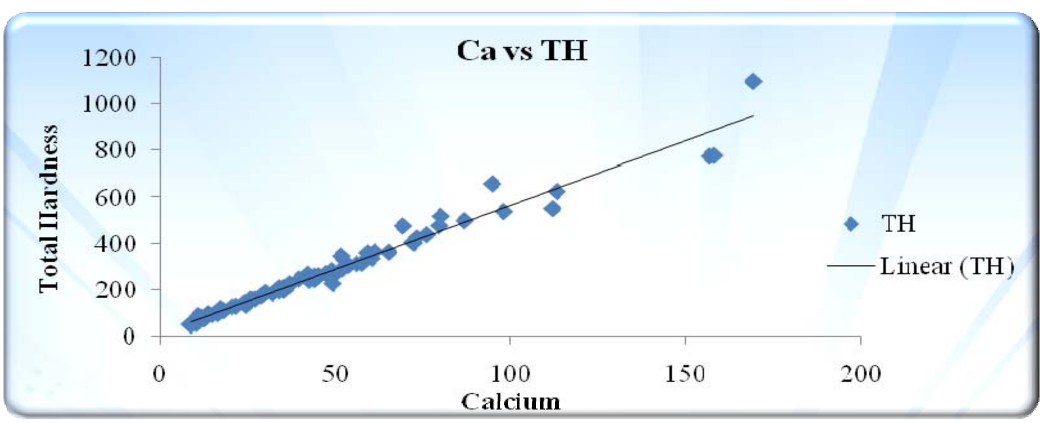

Figure 7: Correlation between Calcium and Total Hardness in Post Monsoon Season

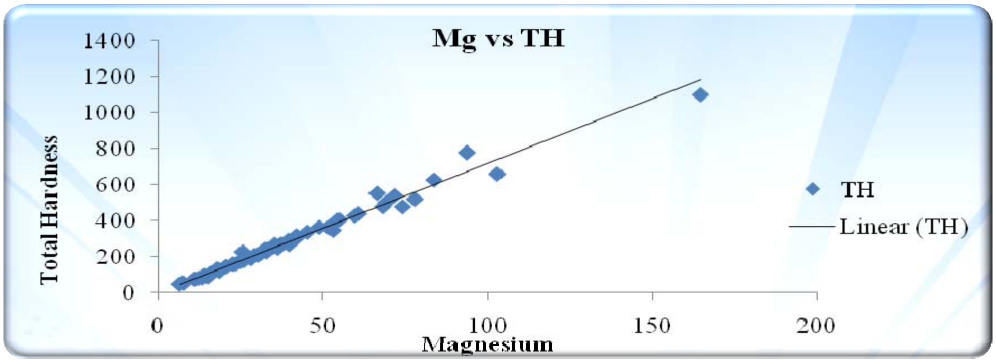

Figure 8: Correlation between Magnesium and Total Hardness in Post Monsoon Season

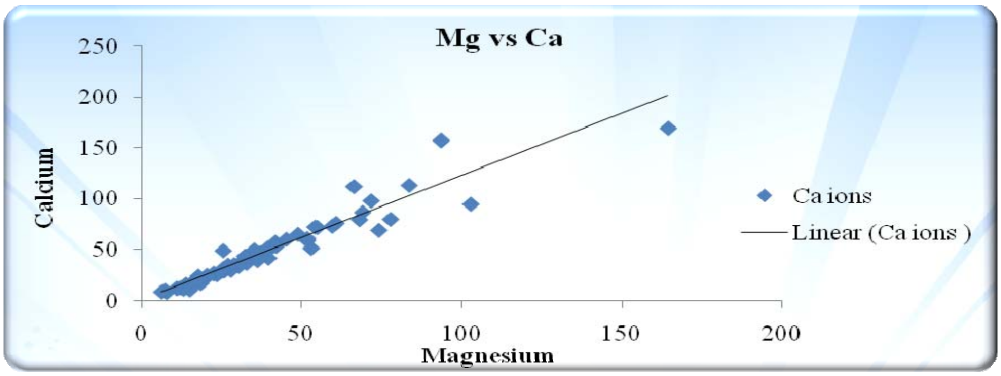

Figure 9: Correlation between Magnesium and Calcium in Post Monsoon Season

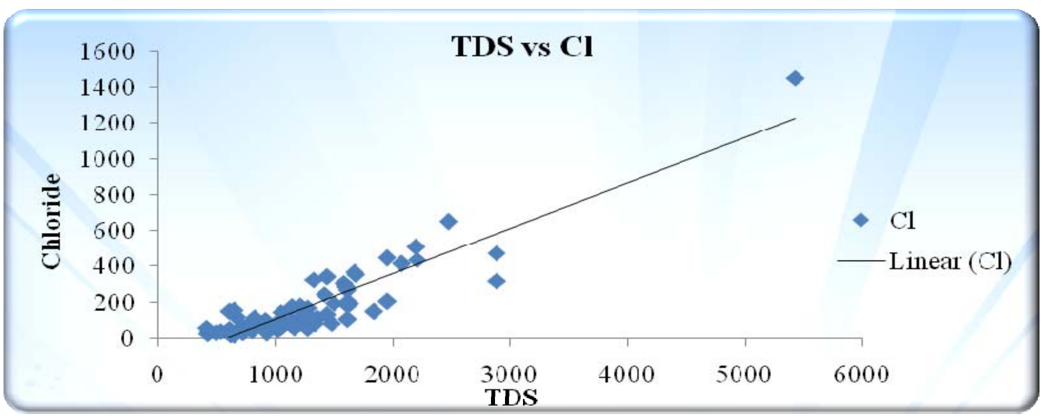

Figure 10: Correlation between TDS and Chloride in Post Monsoon Season

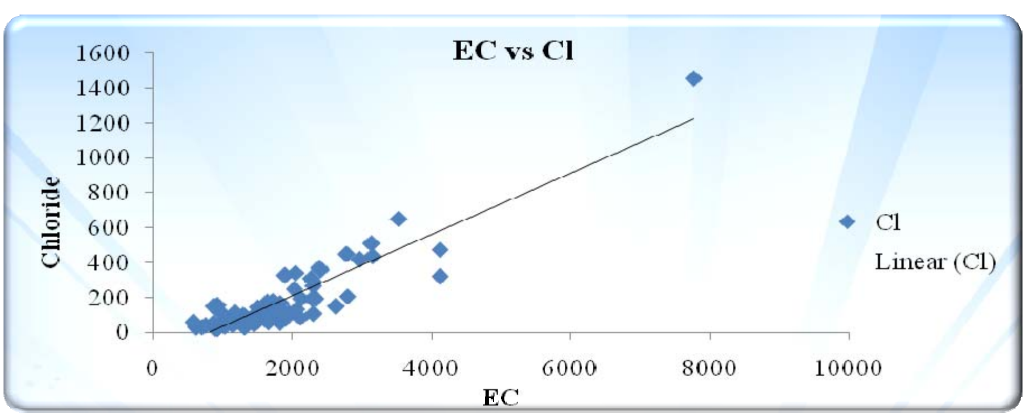

Figure 11: Correlation between EC and Chloride in Post Monsoon Season

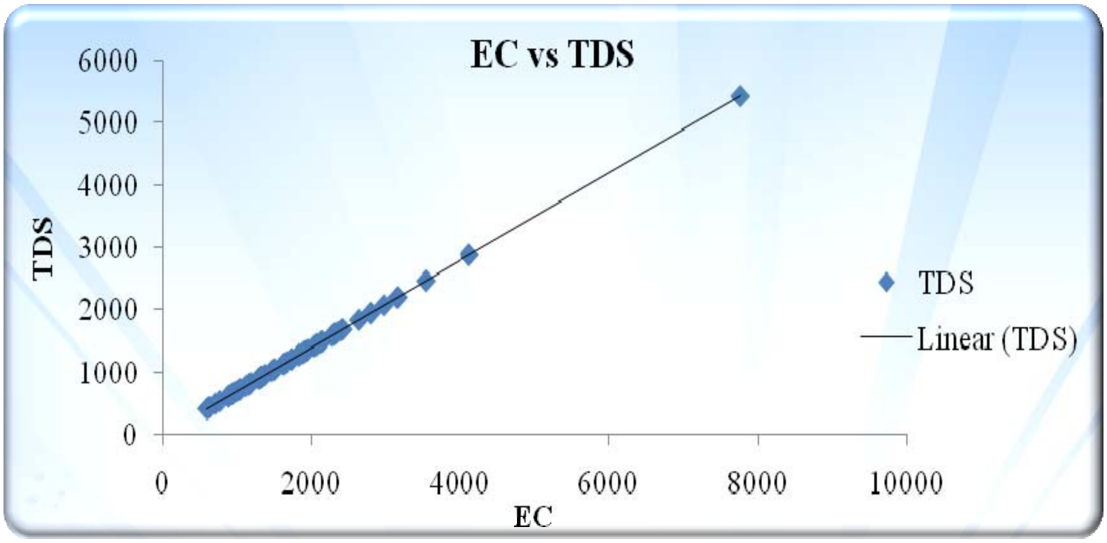

Figure 12: Correlation between EC and TDS in Post Monsoon Season

Table 4: Physico-Chemical Characteristics of Groundwater Samples – Post Monsoon Season

S.No.	Village	Source	Sample No.	pH	TA	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
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
		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

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

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

Table 6: Correlation matrix of water quality parameters in Pre Monsoon season

Parameter	pH	TA	TH	Ca^{+2}	Mg^{+2}	Cl^-	NO_3^-	F^-	TDS	EC
pH	1.0000									
TA	0.1225	1.0000								
TH	-0.4690	-0.0085	1.0000							
Ca^{+2}	-0.4616	-0.0421	**0.9861**	1.0000						
Mg^{+2}	-0.4657	0.0183	**0.9912**	**0.9555**	1.0000					
Cl^-	-0.3484	0.0623	0.6414	0.5932	0.6131	1.0000				
NO_3^-	-0.0767	0.0122	0.3409	0.3017	0.3652	0.2947	1.0000			
F^-	0.2015	0.4017	-0.1816	-0.1688	-0.1881	-0.2339	-0.0958	1.0000		
TDS	-0.2449	0.2384	0.6848	0.6312	0.7137	**0.9130**	0.3373	-0.0731	1.0000	
EC	-0.2448	0.2385	0.6847	0.6312	0.7136	**0.9129**	0.3372	-0.0729	**0.9999**	1.0000

Table 7: Correlation matrix of water quality parameters in Post Monsoon season

Parameter	pH	TA	TH	Ca^{+2}	Mg^{+2}	Cl^-	NO_3^-	F^-	TDS	EC
pH	1.0000									
TA	0.0892	1.0000								
TH	-0.2515	-0.1116	1.0000							
Ca^{+2}	-0.2165	-0.1262	**0.9833**	1.0000						
Mg^{+2}	-0.2731	-0.0976	**0.9898**	**0.9475**	1.0000					
Cl^-	-0.1684	0.1079	0.6895	0.6383	0.7137	1.0000				
NO_3^-	-0.0647	-0.1857	0.3858	0.4497	0.3269	0.1224	1.0000			
F^-	0.1238	0.4104	-0.1419	-0.1412	-0.1391	-0.0608	-0.0932	1.0000		
TDS	-0.1402	0.3048	0.63803	0.5788	0.6695	**0.9116**	0.1129	0.0867	1.0000	
EC	-0.1401	0.3048	0.63804	0.5789	0.6696	**0.9116**	0.1129	0.0868	**0.9999**	1.0000

Regression Analysis

The linear regression analysis was found to have better and higher level of significance with their correlation coefficients. The regression equation (Y = aX+b) obtained from the analysis are given in Table-8, 10, 12 and 14 for both pre and post monsoon seasons. The different dependent characteristics of water quality were calculated by using the developed regression equations and by substituting the values for the independent variables in the equations. Table-9, 11, 13 and 15 depict the experimentally observed and predicted values for the dependent parameters followed by the percentage error (%e) for pre and post monsoon seasons, respectively. Linear regression equations are developed with the assumptions that change in dependent variable (Y) is either directly or indirectly proportional to the change in the independent variable (X).

Table 8: Regression equation for pairs of parameters having highly significant correlation coefficients (0.8<r<1.0) in Pre monsoon season

Pairs of Parameters	Correlation Coefficient	R^2	Adjusted R^2	Regression Coefficients		Regression Equation	Sig.
X-Y	**R**			**a**	**b**	**Y= aX+b**	
Ca-TH	0.9861	0.9723	0.9715	5.5118	14.9451	TH= 5.5118 Ca + 14.9451	0.02
Mg-TH	0.9912	0.9824	0.9819	7.2336	-1.5989	TH= 7.2336Mg -1.5989	0.24
Mg-Ca	0.9555	0.9129	0.9103	1.2473	-0.6484	Ca= 1.2473 Mg -0.6484	0.02
TDS-Cl	0.913	0.8335	0.8286	0.2985	-252.552	Cl= 0.2985 TDS -252.552	0.00
EC-Cl	0.9129	0.8334	0.8285	0.2089	-252.458	Cl = 0.2089 EC – 252.458	0.00
EC-TDS	0.9999	0.9998	0.9997	0.6999	0.2287	TDS = 0.6999 EC + 0.2287	0.02

In above Table: 8 R^2 values in pre-monsoon season indicate that 97.23% and 98.24% total hardness can be explained by calcium and magnesium respectively. 91.29% calcium can be explained by magnesium. TDS can explain 83.35% chloride while EC can explain 83.34% of chloride and 99.98% TDS can be explained by EC. Values of adjusted R^2 are very close to R^2 values that mean the variables have adequate predictive ability for dependent variables. Out of the six significance values five are under 0.05 so almost all the variable are significant.

Table 9: Observed parameter, predicted parameter and percent error of the pair of parameters having highly significant correlation coefficients (0.8<r<1.0) in Pre monsoon season

Pair of Parameters	Independent Variable	Dependent Variable	X value	Y (observed)	Y (predicted)	% Error
Ca-TH	Ca	TH	44.49	260.19	260.16	0.011
Mg-TH	Mg	TH	36.19	260.19	260.18	0.003
Mg-Ca	Mg	Ca	36.19	44.49	44.49	0.00
TDS-Cl	TDS	Cl	1589.88	222.01	222.03	-0.009
EC-Cl	EC	Cl	2271.05	222.01	221.96	0.022
EC-TDS	EC	TDS	2271.05	1589.88	1589.74	0.008

Table 10: Regression equation for pairs of parameters having moderate significant correlation coefficients (0.6<r<0.8) in Pre monsoon season

Pairs of Parameters	Correlation Coefficient	R^2	Adjusted R2	Regression Coefficients		Regression Equation	p value
X-Y	R			a	b	Y= aX+b	Sig.
Cl-TH	0.6414	0.4114	0.3941	0.4458	161.2194	TH = 0.4458 Cl + 161.2194	0.00
TDS-TH	0.6848	0.4689	0.4533	0.1537	15.8022	TH = 0.1537 TDS + 15.8022	0.66
EC-TH	0.6847	0.4688	0.4532	0.1076	15.8504	TH = 0.1076 EC + 15.8504	0.66
TDS-Ca	0.6312	0.3984	0.3807	0.0253	4.1939	Ca = 0.0253 TDS + 4.1939	0.54
EC-Ca	0.6312	0.3984	0.3807	0.0177	4.2016	Ca = 0.0177 EC + 4.2016	0.54
Cl-Mg	0.6131	0.3759	0.3575	0.0635	22.0878	Mg = 0.0635 Cl + 22.0878	0.46
TDS-Mg	0.7137	0.5094	0.4950	0.0219	1.2862	Mg = 0.0219 TDS + 1.2862	0.00
EC-Mg	0.7136	0.5092	0.4948	0.0154	1.2932	Mg = 0.0154 EC + 1.2932	0.00

Table 11: Observed parameter, predicted parameter and percent error of the pair of parameters having moderate significant correlation coefficients (0.6<r<0.8) in Pre monsoon season

Pair of Parameters	Independent Variable	Dependent Variable	X value	Y (observed)	Y (predicted)	% Error
Cl-TH	Cl	TH	222.01	260.1972	260.1914	0.002
TDS-TH	TDS	TH	1589.88	260.19	260.17	0.007
EC-TH	EC	TH	2271.05	260.19	260.21	-0.007
TDS-Ca	TDS	Ca	1589.88	44.49	44.42	0.157
EC-Ca	EC	Ca	2271.05	44.49	44.39	0.224
Cl-Mg	Cl	Mg	222.01	36.19	36.18	0.027
TDS-Mg	TDS	Mg	1589.88	36.19	36.11	0.22
EC-Mg	EC	Mg	2271.05	36.19	36.26	-0.19

Table:10 clearly depicts that in pre monsoon season 41.14%, 46.89% and 46.88% total hardness can be predicted by chloride, TDS and EC respectively. TDS and EC both can explain 39.84% of calcium. Magnesium can be explained 37.59% by chloride, 50.94% by TDS and 50.92% by EC. Adjusted R^2values are close to estimated R^2 which indicate the relevancy and utility of regression model. The p-value for TH and magnesium are 0.00 indicating that they are significantly related to their independent variable. The remaining parameters have higher p values indicating that they are not related to a level of 0.05.

Table 12: Regression equation for pairs of parameters having highly significant correlation coefficients (0.8<r<1.0) in Post monsoon season

Pairs of Parameters	Correlation Coefficient	R^2	Adjusted R2	Regression Coefficients		Regression Equation	Sig.
X-Y	R			a	b	Y= aX+b	
Ca-TH	0.9833	0.9669	0.9659	5.5289	14.4578	TH= 5.5289 Ca + 14.4578	0.04
Mg-TH	0.9898	0.9797	0.9791	7.1647	1.4224	TH= 7.1647 Mg + 1.4224	0.80
Mg-Ca	0.9475	0.8978	0.8948	1.2198	0.5590	Ca= 1.2198 Mg + 0.5590	0.81
TDS-Cl	0.9116	0.8310	0.8260	0.2525	-145.161	Cl= 0.2525 TDS -145.161	0.00
EC-Cl	0.9116	0.8310	0.8260	0.1767	-145.152	Cl = 0.1767 EC – 145.152	0.00
EC-TDS	0.9999	0.9998	0.9997	0.7000	0.0672	TDS = 0.7000 EC + 0.0672	0.34

Table 13: Observed parameter, predicted parameter and percent error of the pair of parameters having highly significant correlation coefficients (0.8<r<1.0) in Post monsoon season

Pair of Parameters	Independent Variable	Dependent Variable	X value	Y (observed)	Y (Predicted)	% Error
Ca-TH	Ca	TH	47.35	276.26	276.25	0.003
Mg-TH	Mg	TH	38.36	276.2676	276.2602	0.002
Mg-Ca	Mg	Ca	38.36	47.3521	47.3505	0.003
TDS-Cl	TDS	Cl	1252.28	171.04	171.03	0.005
EC-Cl	EC	Cl	1788.87	171.04	170.94	0.058
EC-TDS	EC	TDS	1788.87	1252.28	1252.27	0.0007

In above Table: 12 R^2 values in post-monsoon season indicate that 96.69% and 97.97% total hardness can be explained by calcium and magnesium respectively. 89.78% Calcium can be explained by magnesium. TDS and EC both can explain 83.10% of chloride and 99.97% TDS can be explained by EC. Values of adjusted R^2 are very close to R^2 values that mean the variables have adequate predictive ability for dependent variables. Out of the six significance values three are under 0.05 indicating that the model applied is significantly good enough in predicting the dependent variables ($p > 0.05$).

Table 14: Regression equation for pairs of parameters having moderate significant correlation coefficients (0.6<r<0.8) in Post monsoon season

Pairs of Parameters	Correlation Coefficient	R^2	Adjusted R^2	Regression Coefficients		Regression Equation	Sig.
X-Y	R			a	b	Y= aX+b	
Cl-TH	0.6895	0.4754	0.4599	0.6531	164.5563	TH = 0.6531 Cl + 164.5563	0.00
TDS-TH	0.63803	0.40708	0.38964	0.1674	66.6619	TH = 0.1674 TDS + 66.6619	0.06
EC-TH	0.63804	0.40709	0.38965	0.1172	66.6695	TH = 0.1172 EC + 66.6695	0.06
Cl-Ca	0.6383	0.4074	0.3899	0.1075	28.9611	Ca = 0.1075 Cl + 28.9611	0.00
Cl-Mg	0.7137	0.5094	0.4949	0.0934	22.3872	Mg = 0.0934 Cl + 22.3872	0.00
TDS-Mg	0.6695	0.4482	0.4320	0.0243	7.9720	Mg = 0.0243 TDS + 7.9720	0.09
EC-Mg	0.6696	0.4483	0.4321	0.0169	7.9731	Mg = 0.0169 EC + 7.9731	0.09

Table 15: Observed parameter, predicted parameter and percent error of the pair of parameters having moderate significant correlation coefficients (0.6<r<0.8) in Post monsoon season

Pair of Parameters	Independent Variable	Dependent Variable	X value	Y (observed)	Y (Predicted)	% Error
Cl-TH	Cl	TH	171.04	276.2676	276.2625	0.001
TDS-TH	TDS	TH	1252.28	276.26	276.29	-0.01
EC-TH	EC	TH	1788.87	276.26	276.32	-0.021
Cl-Ca	Cl	Ca	171.04	47.35	47.34	0.021
Cl-Mg	Cl	Mg	171.04	38.36	38.35	0.026
TDS-Mg	TDS	Mg	1252.28	38.36	38.40	-0.104
EC-Mg	EC	Mg	1788.87	38.36	38.21	0.391

Table:14 clearly depicts that in post monsoon season 47.54%, 40.7% and 40.7% total hardness can be predicted by chloride, TDS and EC respectively. Chloride can explain 40.74% calcium. Magnesium can be explained 50.94% by chloride, 44.82% by TDS and 44.83% by EC. Adjusted R^2values are close to estimated R^2 which indicate the relevancy and utility of regression model. The p- value for TH, calcium and magnesium are 0.00 indicating that they are significantly related to Chloride. The remaining parameters have slightly higher p values indicating that they are not related to a level of 0.05.

CONCLUSIONS

From the above results it can be concluded that out of the all pairs, six pairs of water quality parameters i.e. Ca^{+2}-TH, Mg^{+2}-TH, Mg^{+2}-Ca^{+2}, TDS-Cl^-, EC- Cl^- and EC-TDS shows high degree of linear relationship (high correlation coefficient ‘r’) between them in both seasons.TDS and EC exhibits highest value of correlation coefficient in both pre and post monsoon seasons. In fact, we can say that, they have perfect linear relationship between them. These parameters are also very important as they share linear relationship with most of the other water quality parameters.

Calculated R^2 values suggest that dependent variables can be well predicted from the independent variables. Adjusted R^2 values are close to estimated R^2 values supporting the adequate predictive ability for dependent variables, also the relevancy and utility of regression model. p-values less than 0.05 indicates that the model applied is significantly good enough in predicting the dependent variables though values greater than 0.05 suggests that variables are not related to a significance level of 0.05.

Regarding water quality the results of current study revealed that ground water, used by the people residing in villages of Bassi Tehsil, is not suitable for drinking purpose. So, there is a need of continuous monitoring of water quality and proper environment management plan must be adopted to control drinking water pollution immediately. Based on these results and analysis of water samples, it is also recommended to use water only after boiling and filtering or by reverse osmosis treatment for drinking purpose by the individuals to prevent adverse health effects.

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