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Application Of Correlation And Regression Analysis In Assessing Ground Water Quality

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Abstract: Ground water samples were collected from 30 locations in Virudhunagar district, Tamil nadu was assessed in the winter, summer and rainy season from July 2008 to June 2009. Water quality assessment was carried out for the parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), chloride, sulphate, bicarbonate, corbonate, calcium, magnesium, sodium, potassium, dissolved oxygen (DO), chemical oxygen demand (COD) and biological oxygen demand (BOD). Correlation coefficients were determined to identify the highly correlated and interrelated water quality parameters (WQPs). Regression equations relating these identified and correlated parameters were formulated for highly correlated WQPs. Comparison of observed and estimated values of the different WQPs parameters reveals that the regression equations developed in the study can be very well used for making water quality monitoring by observing the above said parameters alone. This provides an easy and rapid method of monitoring of water quality of the water system studied.
Keywords: Assessment, Water quality, season, Correlation and Regression Analysis.

INTRODUCTION

Water is our most valuable natural resource. This fact though recognized by man has not stopped him from polluting the rivers, lakes and oceans. The cause of water pollution could be municipal, agricultural and industrial. All these major causes have rampantly deteriorated the quality of water the world over. This has resulted in the decrease in the quality of drinking water available, and has also caused the decline of resources from our marine sources as the runoff water from the land is ultimately destined for the seas[1]. Ground water is the only alternative option for even the urban centre's having well planned, designed and executed water supply systems like Virudhunagar district, during the periods of water scarcity due to shortfall of rain or its non-occurrence. Also normally the ground water is the water source for different locations, where the municipal water supply facilities are not made available. Now a days, the ground water potential and its quality level in major cities and urban centre's is getting deteriorated due to the population explosion, urbanization, industrialsation and also the failure of monsoon and improper management of rain water. The ground water quality is normally characterized by different physico-chemical characteristics. These parameters change widely due to the type of pollution, seasonal fluctuation, ground water extraction, *etc*. Monitoring of water quality levels is thus important to assess the levels of pollution and also to assess the potential risk to the environment.

[2]Sunitha et al. identified that the Electrical conductivity finds higher level correlation significance with many of the water quality parameters, like total dissolved solids, chlorides, total alkalinity, sulphate, carbonates , total hardness and magnesium. [3]Mahajan et al. identified that all the parameters are more or less correlated with others in the correlation and regression study of the physico - chemical parameters of ground water. [4]Kalyanaraman identified that the water quality of ground water can be predicted with sufficient accuracy just by the measurement of EC alone. This provides a means for easier and faster monitoring of water quality in a location. [5]Achuthan Nair et al. concluded that the correlation study and correlation coefficient values can help in selecting treatments to minimize contaminates in ground water.

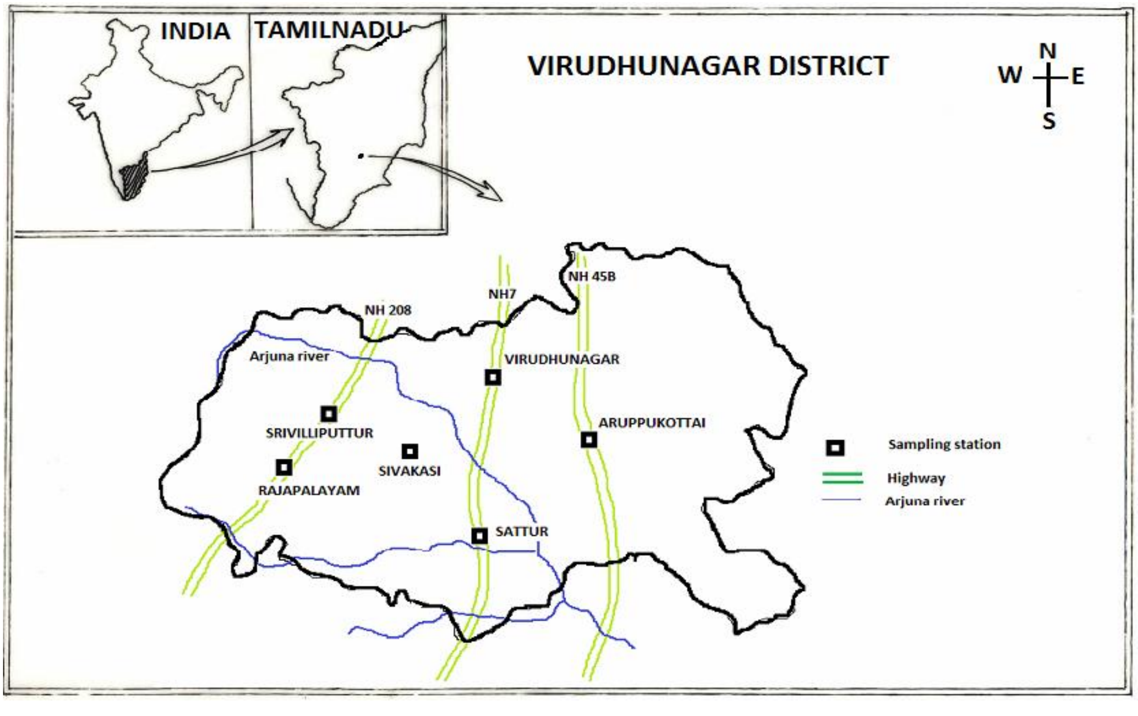
Virudhunagar district (Figure. 1) is situated in the southern portion of Tamil Nadu. Spread in area is 4283 km^2. It is about 43 kilometers to the south of temple city Madurai. Tirunelveli district lies to the southwest, Kerala to the west, and Theni district to the nouth west. It comprises eight taluks namely Aruppukkottai, virudhunagar, Rajapalam, Sattur, Sivakasi, Srivilluputtur and Tiruchuli. Sivakasi, a town famous for fireworks, printing press, match boxes is about 27 km from virudhunagar[6]. In recent years, a growing number of studies stressed the unscientific disposal of wastes (domestic and industrial), which has caused immense proplems not only to human but also to the aquatic environment. As the consequences of population exploitation, unbanization, industrialization and modern agricaultural techniques, the massive waste disposals to the environment and it threat to the ground water quality.

EXPERIMENTAL

Water samples from the selected sites were collected during July 2008-June 2009 and taken in pre-cleaned polyethylene bottles; the samples after collection were immediately placed in dark boxes and processed within 6 h of collection.

The collected samples were analyzed for major physical and chemical water quality parameters like pH, EC, TDS, TA, Total hardness, chloride, sulphate, bicarbonate, corbonate, calcium, magnesium, sodium, potassium, dissolved oxygen (DO), chemical oxygen demand (COD) and biological oxygen demand (BOD) as per the method Assessment of Ground Water Quality described in “Standard methods for the examination of water and wastewater American Public Health Association (APHA, 1992)[7]. The parameters present in the water sample can be calculated by using various methods.

In the present study, the parameters such as pH, EC, TDS, TA, total hardness, chloride, sulphate, bicarbonate, corbonate, calcium, magnesium, sodium, potassium, dissolved oxygen (DO), chemical oxygen demand (COD) and biological oxygen demand (BOD) were considered and the basic statistics and correlation coefficients among all these water quality characteristics were calculated[8]. The linear regression equation was developed for the pairs having strong correlation and also for the pair of parameters, which have influence on each other. The correlation analysis on water quality parameters revealed that all parameters were more or less correlated with each other. The characteristics were calculated using the regression equations and then compared with the observed values.



Methods used for analysis of quality parameters for water samples:

Quality parameter studied	**Method used**
pH	Recorded by pH meter
Electrical Conductitivity, EC	Measured by conductivity meter
Total Dissolved solids, TDS	Evaporation method
Total Alkalinity, TH	Neutralising with standard HCl
Total Hardness,TH	EDTA titration
Chloride, Cl^-	Mohr's method
Sulphate, $SO_4{}^{2-}$	Gravimetric method
Calcium Hardness, CaH	EDTA titration
Magnesium Hardness, MgH	EDTA titration
Sodium, Na^+	Flame photometric method
Pottasium, K^+	Flame photometric method
Dissolved oxygen, DO	Winkler's method
Chemical oxygen demand, COD	Winkler's method
Biological oxygen demand, BOD	Winkler's method

RESULTS AND DISCUSSION

Physico-chemical characteristic analysis made on ground water collected from 30 locations of the study area in winter, summer, and rainy season reveals that there were considerable deviations in the water quality parameters for the water quality standards. Also the variations in the concentration for each parameter are wider.[9]

The relationship between two variables is the correlation coefficient which shows how one variable predicts the other. Associated with correlation coefficient is r, which is the percentage of varience in the dependent variable, explained by the independent variable[10] .

The results of the correlation analysis are considered in the subsequent interpretation. A high correlation coefficient (nearly 1 or -1) means a good relationship between two variables, and a correlation coefficient around zero means no relationship. Positive values indicate a positive relationship while negative values of r indicate an inverse relationship.

The correlation coefficients (r) among various water quality parameters of ground water of the study area in winter, summer and rainy season were calculated and the values of correlation coefficients (r) are given in Table 1, 2 and 3, respectively.

Table - 1 Correlation matrices for water quality parameters during winter season

WQPs	EC	TDS	TA	TH	Cl^-	SO_4^{2-}	SO_3^{2-}	HCO_3^{2-}	CO_3^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	DO	COD	BOD
EC	1	0.920	0.724	0.732	0.792	0.826	0.596	0.495	0.774	0.596	0.519	0.487	0.470	0.11	0.73	-0.13
TDS		1	0.802	0.814	0.852	0.874	0.640	0.520	0.786	0.676	0.602	0.470	0.553	0.12	0.84	-0.21
TA			1	0.887	0.484	0.860	0.649	0.606	0.462	0.767	0.758	0.239	0.533	-0.11	0.80	-0.31
TH				1	0.406	0.819	0.576	0.541	0.557	0.899	0.872	0.290	0.369	-0.10	0.76	-0.22
Cl^-					1	0.648	0.476	0.291	0.758	0.289	0.187	0.502	0.536	0.32	0.64	-0.16
SO_4^{2-}						1	0.724	0.749	0.692	0.639	0.605	0.459	0.543	-0.09	0.85	-0.40
SO_3^{2-}							1	0.727	0.548	0.411	0.380	0.540	0.407	-0.03	0.71	-0.38
HCO_3^{2-}								1	0.390	0.231	0.244	0.251	0.466	-0.37	0.57	-0.34
CO_3^{2-}									1	0.455	0.372	0.495	0.242	0.22	0.66	0.04
Ca^{2+}										1	0.972	0.244	0.279	0.07	0.64	-0.13
Mg^{2+}											1	0.165	0.219	0.12	0.64	-0.18
Na^+												1	0.276	0.13	0.43	-0.23
K^+													1	-0.11	0.42	-0.26
DO														1	0.28	0.06
COD															1	-0.351
BOD																1

The results of the statistical analysis which are shown in table 1 (winter season) gave an indication that EC has a positive and signification correlation with TDS, TA, TH, Cl^- , SO_4^{2-}, CO_3^{2-}, and COD, weak correlation with DO and negative correlation with BOD. TDS has positive and significant correlation with TA, TH, Cl^- , SO_4^{2-}, CO_3^{2-}, and COD, weak correlation with DO and negative correlation with BOD. TA has positive and signification correlation with TH, SO_4^{2-}, Calcium, magnesium and COD; weak correlation with Na^+, and negative correlation DO and BOD. Total hardness has positive and signification correlation with SO_4^{2-}, calcium, magnesium and COD, weak correlation with Na^+ and negative correlation with DO and BOD. Chloride has positive and signification correlation with pH, EC, TDS, SO_4^{2-}, CO_3^{2-}, and COD, weak correlation with SO_3^{2-}, HCO_3^{2-}, calcium, magnesium sodium, potassium and DO and negative correlation with BOD. Sulphate has positive and signification correlation with pH, EC, TDS, TA, TH, SO_3^{2-}, HCO_3^{2-}, COD, weak correlation with sodium and negative correlation with DO and BOD. Sulphite has positive and signification correlation pH, EC, TDS, Cl^-, HCO_3^{2-}, COD, weak correlation with sodium and chloride and negative correlation with DO and BOD. Carbonate, sodium, potassium DO and BOD are weakly correlated with most of the water quality parameters. Calcium has positive and signification correlation with TH, TA and magnesium, weak correlation with chloride, sodium, potassium bicarbonate, dissolved oxygen and negative correlated with BOD. Magnesium has positive and signification correlation with TH, TA and calcium, weak correlation with chloride, sodium, potassium bicarbonate, dissolved oxygen and negative correlated with BOD.

In summer season (Table 2), EC has positive and signification correlation with TA, TH, Cl^- , SO_4^{2-}, CO_3^{2-}, weak correlation with potassium and negative correlation with DO and BOD. TDS has positive and signification correlation with EC, TA, TH, Cl^- SO_4^{2-}, CO_3^{2-}, calcium, magnesium and COD, weak correlation with potassium and negative correlated with DO BOD. TA has positive and signification correlation with TH, SO_4^{2-}, SO_3^{2-}, HCO_3^{2-}, calcium, magnesium and COD, weak correlation with sodium and potassium and negative correlation with DO and BOD. Total hardness has positive and signification correlation with SO_4^{2-}, calcium, magnesium and COD, weak correlation with sodium and potassium and negative correlation with DO and BOD. Chloride has positive and signification correlation with SO_4^{2-}, CO_3^{2-}, and COD, weak correlation with magnesium, potassium and DO and negative correlation with BOD. Sulphate has positive and signification correlation with SO_3^{2-}, HCO_3^{2-} , CO_3^{2-}, calcium, magnesium and COD, weak correlation with potassium and negative correlation with DO BOD. Sulphite has positive and significant correlation with HCO_3^{2-} and COD, weak correation with magnesium and potassium and negative correlation with DO and BOD. Bicarbonate has weak correlated with most of the parameter like CO_3^{2-} calcium, magnesium, sodium etc., strongly correlated with SO_4^{2-}, SO_3^{2-} and negative correlation with DO and BOD. Carbonate has positive and significance correlation with pH, EC, TDS, Cl^{--}, SO_4^{2}-, weak correlation with potassium and dissolved oxygen and negative correlation with BOD. Calcium has positive and significance correlation with TH, SO_4^{2-}, TDS magnesium, weak correlation with chloride, carbonate, sodium, potassium, and negative correlated with DO and BOD. Magnesium has positive and significance correlated with TH, TA, TDS and calcium, weak correlation with pH, chloride DO, and potassium and negative correlation with BOD. Sodium has positive and signification correlation with pH, weak correlation with TA, TH, HCO_3^{2-}, potassium, and dissolved oxygen and negative correlation with BOD. Potassium has weak correlation with calcium, carbonate and total hardness and negatively correlated with DO and BOD[11].

In rainy season (Table3), significant positive correlation were found between EC and TDS, EC and TA, EC and chloride, weak correlation were found between EC and sodium, EC and potassium. TDS has positive and significance correlation with total alkalinity and chloride, weak correlation with sulphate and sodium and negative correlation with dissolved oxygen and biological demand. Total alkalinity has positive and significant correlation with sulphite bicarbonate and chemical oxygen demand, weak correlation with sulphate and soudium and negative correlation with dissolved and biological demand. Total hardness has moderate correlation with calcium and magnesium weak correlation with chloride, sulphate, sodium and potassium and negative correlation with dissolove oxygen and biological demand. Chloride and sulphate were weakly correlated with most of the water quality parameter and negative correlation with dissolved oxygen and biological demand. Sulphite has positive and significant correlation with total alkalinity, bicarbonate, calcium, magnesium and chemical oxygen demand, weak correlation with potassium and carbonate and negative correlation with dissolved oxygen and biological demand. Bicarbonate has positive and significant correlation with total alkalinity, sulphite, calcium, magnesium and chemical oxygen demand, weak correlation with chloride and negative correlation with dissolved oxygen and biological demand. Carbonate has positive and significant correlation with calcium, magnesium, chemical oxygen demand, weak correlation with pH, chloride, sodium, potassium and dissolved oxygen and negative correlation with biological oxygen demand. Calcium has positive and significant correlation with EC, TDS, TA, TH, sulphite, bicarbonate, magnesium and chemical oxygen demand; weak correlation with pH chloride and sulphate and negative correlation with dissolved oxygen and biological oxygen demand. Magnesium has positive and significant correlation with EC, TDS, TA, TH, sulphite, bicarbonate and calcium, weak correlation with pH, chloride, sulphate and potassium and negative correlation with dissolved oxygen and biological demand. Sodium and potassium were weakly correlated with other water quality parameters.

Table - 2 Correlation matrices for water quality parameters during summer season

WQPs	EC	TDS	TA	TH	Cl^-	SO_4^{2-}	SO_3^{2-}	HCO_3^{2-}	CO_3^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	DO	COD	BOD
EC	1	0.921	0.724	0.750	0.785	0.823	0.597	0.514	0.784	0.600	0.519	0.496	0.278	-0.03	0.78	-0.21
TDS		1	0.806	0.841	0.838	0.878	0.646	0.540	0.810	0.688	0.610	0.484	0.342	-0.08	0.86	-0.28
TA			1	0.905	0.474	0.856	0.648	0.630	0.511	0.740	0.754	0.256	0.366	-0.42	0.77	-0.42
TH				1	0.431	0.828	0.574	0.553	0.570	0.874	0.868	0.320	0.230	-0.30	0.78	-0.31
Cl^-					1	0.653	0.486	0.313	0.790	0.307	0.179	0.493	0.350	0.15	0.65	-0.20
SO_4^{2-}						1	0.735	0.745	0.712	0.627	0.600	0.483	0.392	-0.29	0.81	-0.48
SO_3^{2-}							1	0.727	0.587	0.417	0.362	0.563	0.340	-0.32	0.72	-0.42
HCO_3^{2-}								1	0.422	0.212	0.242	0.262	0.467	-0.49	0.53	-0.36
CO_3^{2-}									1	0.470	0.352	0.494	0.160	0.07	0.68	-0.11
Ca^{2+}										1	0.951	0.288	0.105	-0.12	0.65	-0.25
Mg^{2+}											1	0.195	0.035	-0.10	0.64	-0.28
Na^+												1	0.31	0.06	0.55	-0.21
K^+													1	-0.39	0.16	-0.28
DO														1	0.04	0.28
COD															1	-0.436
BOD																1

Table - 3 Correlation matrices for water quality parameters during rainy season

WQPs	EC	TDS	TA	TH	Cl^-	SO_4^{2-}	SO_3^{2-}	HCO_3^{2-}	CO_3^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+	DO	COD	BOD
EC	1	0.937	0.726	0.523	0.794	0.436	0.611	0.549	0.594	0.682	0.653	0.362	0.383	-0.16	0.54	-0.25
TDS		1	0.77	0.517	0.831	0.383	0.68	0.59	0.629	0.659	0.635	0.433	0.437	-0.18	0.60	-0.30
TA			1	0.635	0.449	0.285	0.757	0.723	0.511	0.688	0.681	0.34	0.569	-0.08	0.73	-0.29
TH				1	0.134	0.132	0.436	0.461	0.506	0.625	0.665	0.127	0.183	-0.01	0.41	-0.02
Cl^-					1	0.491	0.429	0.295	0.34	0.317	0.266	0.311	0.315	-0.20	0.30	-0.30
SO_4^{2-}						1	0.388	0.313	-0.12	0.342	0.238	0.234	0.273	-0.68	-0.04	-0.07
SO_3^{2-}							1	0.729	0.453	0.685	0.706	0.555	0.389	-0.23	0.67	-0.40
HCO_3^{2-}								1	0.507	0.803	0.818	0.547	0.541	-0.17	0.83	-0.32
CO_3^{2-}									1	0.582	0.649	0.312	0.167	0.30	0.73	-0.02
Ca^{2+}										1	0.971	0.445	0.451	-0.12	0.71	-0.18
Mg^{2+}											1	0.404	0.382	-0.03	0.76	-0.22
Na^+												1	0.307	-0.10	0.46	-0.49
K^+													1	-0.05	0.46	-0.29
DO														1	0.26	0.03
COD															1	-0.32
BOD																1

Table 4. Least square of the relation (y=ax+b) among significantly correlated parameters.

Y(Dependent	X(Independent)	Correlation	b	a	Regression equation
Winter season					
EC	TDS	0.919	362.4	1.2884	EC=1.2884(TDS)+362.4
EC	TH	0.732	774.6	1.918	EC=1.918(TH)+774.6
EC	Cl^-	0.792	1490.3	1.930	EC=1.930(Cl^-)+1490.3
EC	SO_4^{2-}	0.826	-205.5	16.87	EC=16.87 (SO_4^{2-})-205.5
TDS	TH	0.826	265.96	1.544	TDS=1.544(TH)+265.96
TDS	Cl^-	0.842	896.3	1.463	TDS=1.463(Cl^-)+896.3
TDS	SO_4^{2-}	0.872	-374.3	12.706	TDS=12.7(SO_4^{2-})-374.3
TDS	Ca^{2+}	0.686	858.7	2.058	TDS=2.058(Ca^{2+})+858.7
TDS	Mg^{2+}	0.613	111.6	2.1624	TDS=2.162(Mg^{2+})+111.6
TH	SO_4^{2-}	0.819	-104.4	6.384	TH=6.384(SO_4^{2-})-104.4
TH	Ca^{2+}	0.899	335.5	1.442	TH=1.442 (Ca^{2+})+335.5
TH	Mg^{2+}	0.872	923.27	0.1648	TH=0.1648(Mg^{2+})+923.2
Ca^{2+}	Mg^{2+}	0.972	93.29	1.4448	Ca^{2+}=1.4448(Mg^{2+})+93.29
Ca^{2+}	SO_4^{2-}	0.659	-81.69	3.103	Ca^{2+}=3.103 (SO_4^{2-})-81.69
Mg^{2+}	SO_4^{2-}	0.605	-116.9	2.494	Mg^{2+}=2.494(SO_4^{2-})-116.9
Summer season					
EC	TDS	0.921	353	1.2933	EC=1.293(TDS)+353
EC	TH	0.749	567.5	2.117	EC=2.117(TH)+567.5
EC	Cl^-	0.79	1476	1.939	EC=1.939(Cl^-)+1476
EC	SO_4^{2-}	0.82	983.77	9.435	EC=9.435(SO_4^{2-})+983.7
TDS	TH	0.8411	110.59	1.693	TDS=1.693(TH)+110.5
TDS	Cl^-	0.84	886.7	1.4688	TDS=1.468(Cl^-)+886.7
TDS	SO_4^{2-}	0.88	-415.4	12.409	TDS=12.409(SO_4^{2-})-415.4
TDS	Ca^{2+}	0.688	871.1	2.005	TDS=2.005(Ca^{2+})+871.1
TDS	Mg^{2+}	0.61	1101	2.170	TDS=2.170(Mg^{2+})+1101
TH	SO_4^{2-}	0.83	-42.87	5.813	TH=5.813 (SO_4^{2-})-42.87
TH	Ca^{2+}	0.874	412.8	1.265	TH=1.265(Ca^{2+})+412.8
TH	Mg^{2+}	0.87	505.6	1.537	TH=1.537(Mg^{2+})+505.6
Ca^{2+}	Mg^{2+}	0.95	90.32	1.1598	Ca^{2+}=1.159(Mg^{2+})+90.32
Rainey season					
EC	TDS	0.94	185.93	1.379	EC=1.379(TDS)+185.9
EC	TH	0.52	1622	0.978	EC=0.978(TH)+1622
EC	Cl^-	0.794	1341	2.327	EC=2.327(Cl^-)+1341
TDS	Cl^-	0.831	853.3	1.656	TDS=1.656(Cl^-)+853.3
TDS	Ca^{2+}	0.659	1055	2.268	TDS=2.268(Ca^{2+})+1055
TDS	Mg^{2+}	0.64	1140	2.717	TDS=2.717(Mg^{2+})+1140
TH	Ca^{2+}	0.625	435.9	1.6907	TH=1.6907 (Ca^{2+})+435.9
TH	Mg^{2+}	0.66	464.56	2.202	TH=2.202(Mg^{2+})+464.5
Ca^{2+}	Mg^{2+}	0.97	37.78	1.1973	Ca^{2+}=1.197(Mg^{2+})+37.78

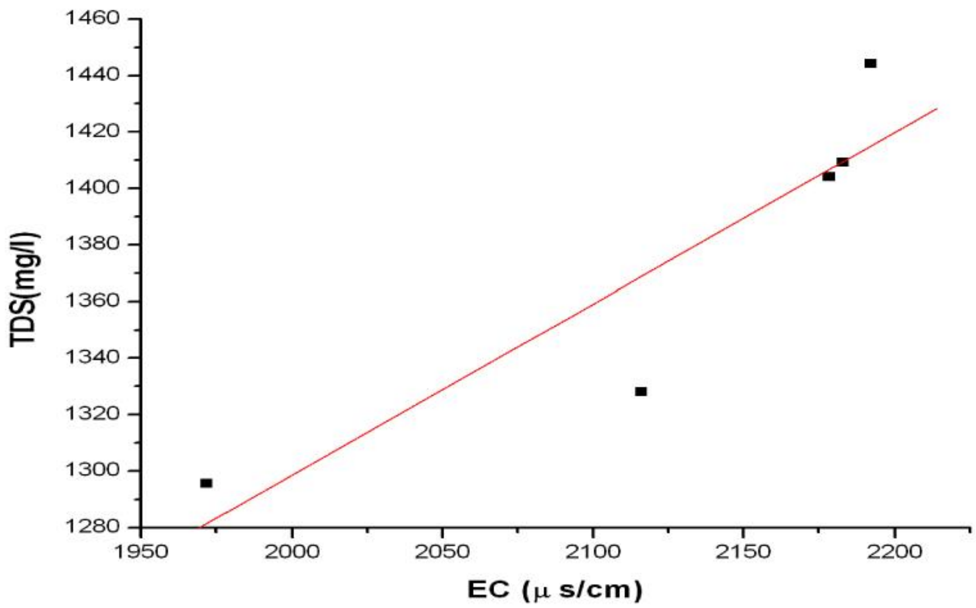


Figure 1. Linear plot between TDS and EC in winter season

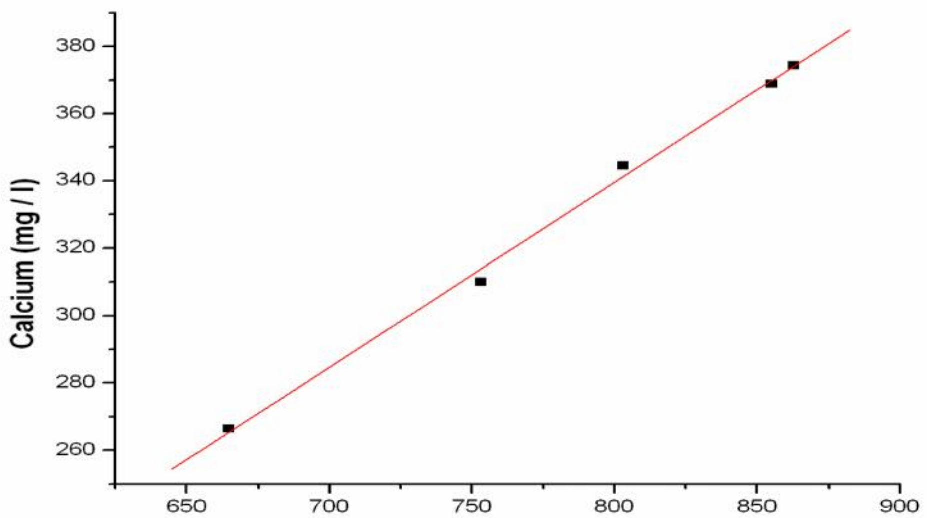


Figure 2. Linear plot between Ca^{2+} and TH of ground water in winter season

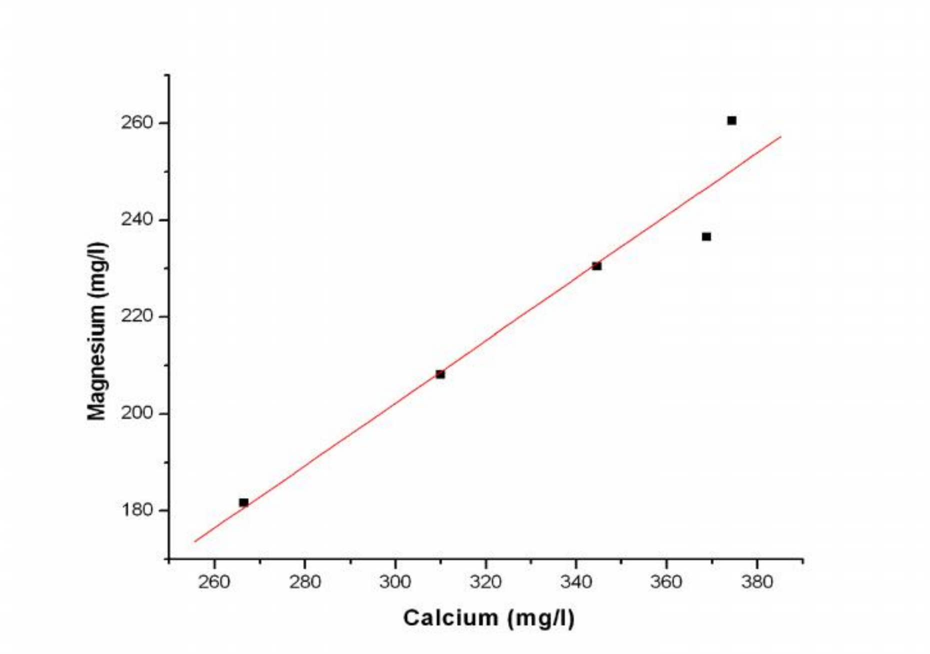


Figure 3. Linear plot between Ca^{2+} and Mg^{2+} of ground water in winter season

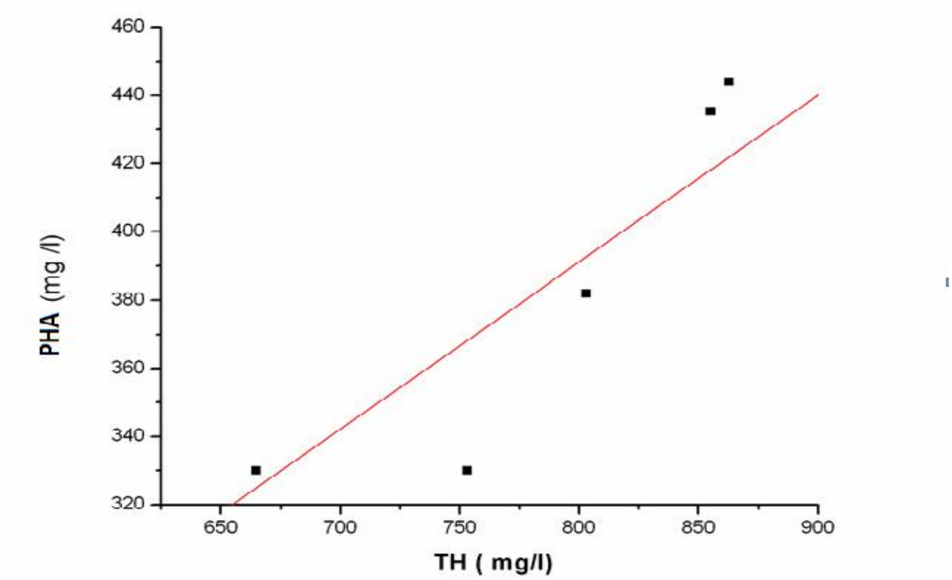


Figure 4 Linear plot between TH and PEH of ground water in presummer season

CONCLUSION:

Results of correlation analysis show that EC and TDS are having high correlation with most of the parameters. Since, the EC finds high correlation with the TDS, TH, chlorides and sulphate, regression equations relating the EC and these parameters were formulated and are given in Table 4 and fig 1. Since the TDS find high correlation with the TH, chlorides and sulphates, regression equations relating these parameters were formulated. Similarly the regression equation between TH and calcium (fig. 2), Calcium and Magnesium (Fig.3), TH and PHA (Fig. 4), TH and sulphate and TH and Magnesium also established. On the basis of the findings of present study, it is recommended that tube well water in the study area should be treated before it is used for drinking purpose.

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