Research Article

Geochemical Assay of Groundwater in Sanganer Tehsil, Jaipur District by Multivariate Analysis

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Abstract

Different evaluation techniques like MATLAB, SPSS etc. have been used to assess geochemical variations in groundwater quality of Sanganer Tehsil, Jaipur, Rajasthan. Samples were analyzed for water quality parameters like pH, EC, TDS, TH, Cl^- , SO_4^{2-}, NO_3^-, F^- etc., using standard techniques and compared with the standard values so as to reveal extent of pollution levels in some villages. Correlation analysis was carried out between various parameters by using SPSS. Some parameters like EC-TDS, TH-TDS, EC-Cl^-, Na^+-TDS etc. exhibited highly positive correlation whereas pH showed negative correlation with most of the parameters. Cluster analysis was also done between different parameters for different villages of Tehsil. Geochemical assay indicates immediate water quality improvement by sustainable management.

Keywords: Correlation SPSS, Water quality management, Cluster analysis, Dendogram

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Introduction

Groundwater is earth's most valued renewable resource for human survival. Over last few decades, competitive economic development and rapid growth in population & urbanization has brought in significant changes in land use. It resulted in excessive demand of water for agriculture and domestic activities. It necessitated a study of parameters of geochemical importance. In this regard, statistical correlation analysis has been found to be useful tool for correlating different parameters. Correlation analyses measures the closeness of relationship between chosen independent and dependent variables. Thus it attempts to establish nature of relationship between various parameters [1-2] and thus provides a mechanism for prediction or forecasting.

Experimental

Materials and Methods

This paper aims to make an assay of water quality index so as to predict ways and means for ascertaining the suitability of ground water for domestic use in Sanganer Tehsil, Jaipur.

Study Area: Sanganer tehsil is attached with main city of Jaipur. Its geographical positioning lies between 26°49'N to 26°51' N latitude and 75°46'E to 75°51' E longitude and has land area of 635.5 sq. km. The climate of the area is hot semiarid with extremes of temperature (15-45°C) and rainfall 650 mm. Water samples of Sanganer area were collected with a view to understand and assess the quality of potable water as now it almost has the status of a suburb of Jaipur.

Water sampling, preservation and data analyses: A total 40 samples were collected from different wells, tube-wells or hand-pumps from 40 villages of Sanganer Tehsil during post-monsoon period [From October 05 to 15, 2014]. All

samples were labeled properly and according to the prerequisites for the analyses of samples. Temperature, pH, electrical conductivity, total dissolved solids, salinity were measured on site using potable meter (PCS Tester 35 Multi-parameter). All other parameters were analyzed according to the standard methods of APHA [3]. Sampling sites with source type are displayed in by using GIS software. (**Table-1 & Figure-1**)

Table 1 Source **&** location of samples of different villages of Sanganer Tehsil

Sample No.	Sampling Source	Village	Sample No.	Sampling Source	Village
S1	Hand Pump	Asawala	S21	Hand Pump	Lakhawas
S2	Hand Pump	Bagru	S22	Well	Laxmipura No. 1
S3	Tube Well	Bagru Rawan	S23	Hand Pump	Mahapura
S4	Hand Pump	Baksawala	S24	Tube Well	Mahel
S5	Well	Bamoriya	S25	Hand Pump	Manoharpura
S6	Well	Bar ka Balaji	S26	Hand Pump	Mohanpura
S7	Hand Pump	Beelwa	S27	Hand Pump	Muhana
S8	Hand Pump	Bhankrota	S28	Tube Well	Nevta
S9	Tube Well	Bhatawala	S29	Hand Pump	Pratapnagar
S10	Hand Pump	Dayalpura	S30	Tube Well	Ramchandrapura
S11	Hand Pump	Durgapura	S31	Tube Well	Ramsinghpura
S12	Tube Well	Goner	S32	Hand Pump	Sanganer
S13	Tube Well	Govindpura	S33	Tube Well	Seemliya
S14	Tube Well	Hajiwala	S34	Tube Well	Shikarpura
S15	Hand Pump	Heerapura	S35	Hand Pump	Sirani
S16	Hand Pump	Jagannathpura	S36	Tube Well	Sitapura
S17	Tube Well	Jaranwala	S37	Tube Well	Sukhdeopura
S18	Hand Pump	Khetapura	S38	Hand Pump	Surajpura
S19	Hand Pump	Khori	S39	Tube Well	Teelawas
S20	Hand Pump	Kishorpura	S40	Tube Well	Vatika

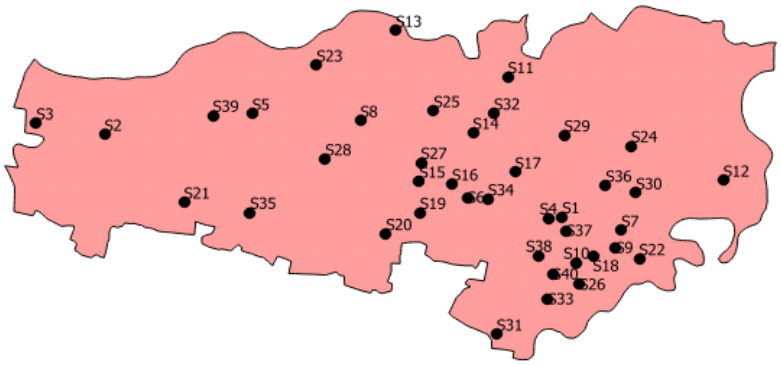

Figure 1 Map of location with different villages of Sanganer Tehsil using GIS

Results and Discussion

Results point out at the quality of groundwater for drinking purpose. Piper trilinear diagram graphically demonstrates the similarities and differences in groundwater Chemistry between the sites.

Field analytical results: Field chemistry measurements were done at every sampling event. Results for field EC ranged from 560µS/cm (S12) to 4506µS/cm (S7) with an average of 1569.83µS/cm and a standard deviation of

910.88µS/cm. W.H.O. defines ~300 µS/cm as permissible value and our investigations reveal that all samples have higher values than permissible limit. Field pH ranged from 7.20 (S30) to 9.00 (S3, S22, S39) with an average of 8.27 and a standard deviation of 0.48. All samples are within the permissible limits of 6.9-9.2 for pH, according to W.H.O. The field temperature ranged from 24˚C (S11, S23) to 26.8˚C (S7, S26, S31) with an average of 25.4˚C and a standard deviation of 0.8˚C. Field salinity ranged from 98 mg/L (S29) to 1028 mg/L (S9) with an average of 328.18 mg/L with a standard deviation of 252.73 mg/L. Results for TDS ranged from 329.50 mg/L (S17) to 1984.26 mg/L (S5) with an average of 775.67 mg/L and a standard deviation of 340.43 [4]. According to W.H.O., TDS values should fall between 500-1500 mg/L. TDS values of 72% sampling sites are on lower side, while 23% are having values in permissible range and 5% samples show higher value than the permissible limit.

Major ion analytical results: Following narration summarizes field results for groundwater samples calculated for analytical results for major and significant cations, anions, TDS and fluoride, in particular.

Analytical results for cations: The results for Na^+ ranged from 43 mg/L (S6) to 602 mg/L (S5) with an average of 160.75 mg/L and a standard deviation value of 106.87. Most of the samples fall in the category of higher range than that of permissible limit of W.H.O., which is 50-60 mg /L. K+, ranged from 1 mg/L (S2, S4, S14, S18 and S35) to 14 mg/L (S28) with an average of 3.20 mg/L and a standard deviation of 2.17. The results for Ca^{2+} ranged between 32 mg/L (S17) to 228 mg/L (S34) with an average of 72.48 mg/L and 34.45 as standard deviation value. Mg^{2+} ranged from 6.00 mg/L (S19) to 97.92 mg/L (S7) with an average of 29.53 mg/L and with standard deviation of 19.56.

Analytical results for anions: The results for Cl^- ranged from 45 mg/L (S17) to 835 mg/L (S5) with an average of 219.6 mg/L and a standard deviation of 152.33. NO_3^- ranged from 5.0 mg/L (S38) to 250.0 mg/L (S7) with an average of 64.50 mg/L and a standard deviation of 46.52. Permissible limit of nitrate is 50 mg/L according to W.H.O. and in our studies it is found to be much higher in most of the samples. HCO_3^- ranged from 95 mg/L (S22) to 878 mg/L (S40) with an average of 284.93 mg/L and with standard deviation value of 136.55. The results for SO_4^{2-} ranged between 0 mg/L (S33, S35 and S38) to 210 mg/L (S7) with an average of 60.13 mg/L and a standard deviation of 45.84. Fluoride ranged from 0.4 mg/L (S38) to 3.5 mg/L (S40) with an average of 1.11 mg/L and a standard deviation of 0.63. Permissible limit for fluoride is 1.0-1.5 mg/L according to W.H.O. standards. The data revealed that 13% samples are affected with high concentration of fluoride as per our investigations.

It has been found that most of the samples are safe only with permeable soil and moderate leaching as 55% samples are in 'Hard' class for TH and 12.5% samples are in 'unsuitable class' for EC values while some samples are unsuitable for irrigation as indicated in **Table-2** for 72.5% samples fall in just 'permissible' class.

Table 2 Quality of water in relation to EC [5], TH and TDS

Parameters	Range	Class	No. of samples	% of samples
			Post-monsoon	Post-monsoon
EC (Wilcox, 1955)	<250	Excellent	0	0.00
	250 – 750	Good	7	17.50
	750 – 2250	Permissible	28	70.00
	2250 – 5000	Unsuitable	5	12.50
	>5000	Unsuitable	0	0.00
TH (Sawyer & McCarty, 1967)	<75	Soft	0	0.00
	75 – 150	Moderate	2	5.00
	150 – 300	Hard	22	55.00
	>300	Very Hard	16	40.00
TDS	<500	Suitable for drinking	6	15.00
	500 – 1000	Permissible	29	72.50
	1000 – 3000	Useful for irrigation	5	12.50
	>3000	Unfit for irrigation	0	0.00

Study on hydrochemical facies: Different hydro-chemical parameters are represented in meq/L in a Piper tri-linear diagram (**Figure-2**) with the help of Aquachem software for evaluating hydrochemistry of groundwater of Sanganer Tehsil. From Piper diagram [6] interpretation of cation concentration of groundwater can be done. It has been found in our studies that sodium-potassium type parameter predominates, whereas anion concentration is dominated by carbonate-bicarbonate type and chloride type. These factors have a negative impact on water quality with regards to irrigation [7].

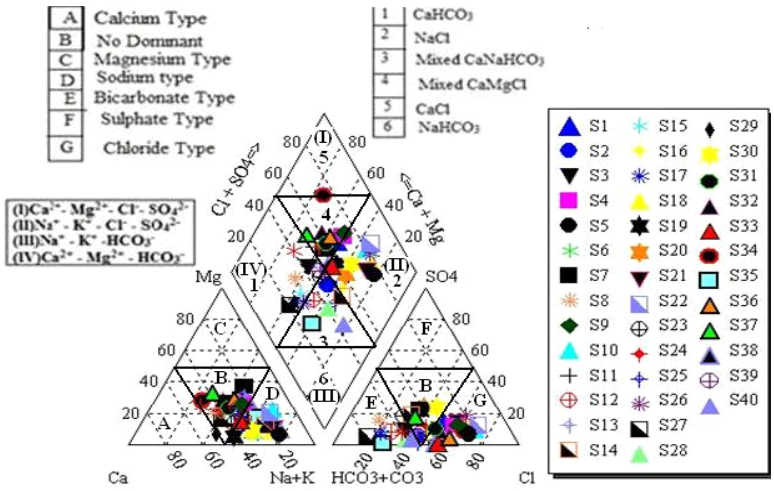

Figure 2 Piper trilinear diagrams of major ion geochemical results of post-monsoon period

Statistical analyses of groundwater parameters: The physico-chemical analysis was carried out using computer software package **SPSS** (**Statistical Package for Social Sciences**, later modified to **Statistical Product and Service Solutions**), version 16.0 SPSS is a comprehensive and flexible statistical analysis and data management solution technique. Descriptive statistics is used to summarize and present data in a meaningful manner so that information can be easily understood. In our studies, Correlation matrix showed relationships of varied types between different hydrochemical parameters. They have been found to be highly positive correlated [**Figure-3 (a) & (b)**], which are indicated in **Table-3** with red color (EC-TDS, EC- Mg^{2+}, TDS-Cl^-, EC-Cl^-, Cl^--Na^+, TDS-Na^+, TA-HCO_3^-, TH-Ca^{2+}, TH-Mg^{2+}, F^--TA, EC-Na^+), positively correlated parameters with blue color (TDS-TH, EC-SO_4^{2-}, TDS with mostly all, Cl^--TH, Na^+-TA) and negatively correlated represented by green color (pH with mostly all, SO_4^{2-}-HCO_3^-, K^+-TH, K^+-SO_4^{2-}, K^+-NO_3^-) with each other. In this study area pH shows negative correlation with most of the variables. It indicates that pH of the samples is an independent variable. The value of EC and TDS indicates good positive correlation with most of the variables pointing to significant role of EC and TDS in our studies.

Table 3 Correlation matrix between different parameters in post-monsoon period

Parameter	Temp.	EC	pH	TDS	HCO_3^-	CO_3^{2-}	TA	TH	Ca^{2+}	Mg^{2+}	Cl^-	F^-	SO_4^{2-}	NO_3^-	Na^+	K^+
Temp.	1															
EC	0.352	1														
pH	-0.060	-0.153	1													
TDS	0.305	0.764	-0.199	1												
HCO_3^-	0.109	0.121	-0.131	0.531	1											
CO_3^{2-}	0.042	0.166	0.224	0.254	0.130	1										
TA	0.112	0.139	-0.100	0.549	0.993	0.249	1									
TH	0.212	0.537	-0.309	0.587	0.31	0.243	0.333	1								
Ca^{2+}	0.144	0.295	-0.287	0.528	0.349	0.213	0.367	0.882	1							

Mg^{2+}	0.230	0.654	-0.253	0.498	0.190	0.211	0.212	0.867	0.53	1						
Cl^-	0.275	0.797	-0.163	0.881	0.193	0.119	0.203	0.515	0.472	0.428	1					
F^-	-0.031	0.086	-0.059	0.406	0.626	0.134	0.628	0.135	0.221	0.011	0.214	1				
SO_4^{2-}	0.253	0.517	-0.304	0.518	-0.029	0.154	-0.010	0.426	0.260	0.492	0.384	0.055	1			
NO_3^-	0.137	0.325	-0.004	0.432	0.264	0.298	0.295	0.309	0.194	0.351	0.119	0.066	0.356	1		
Na^+	0.242	0.616	-0.087	0.877	0.501	0.098	0.501	0.137	0.134	0.105	0.790	0.437	0.343	0.280	1	
K^+	0.165	-0.030	0.193	0.051	0.219	-0.249	0.184	-0.015	0.059	-0.089	0.049	0.310	-0.114	-0.186	0.099	1

*Red, blue & green colors indicate highly positive correlation, positive correlation & negative correlation respectively.

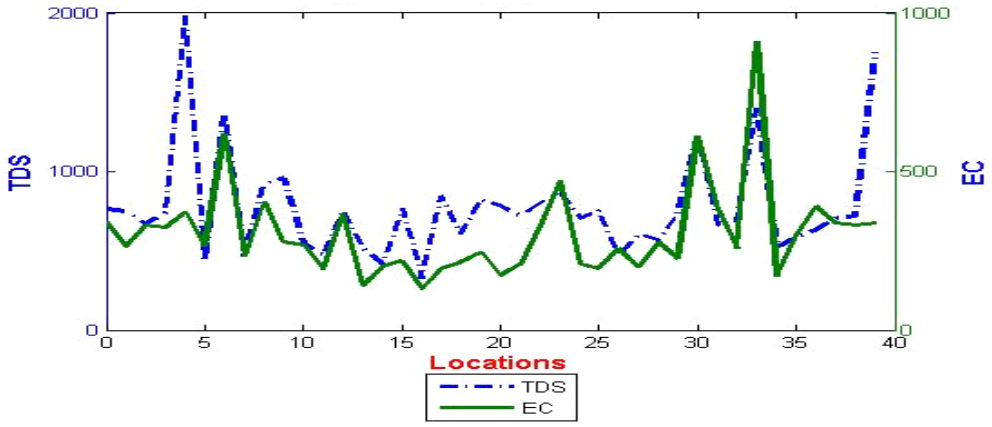

Figure 3a Correlation graph between TDS & EC in post-monsoon period

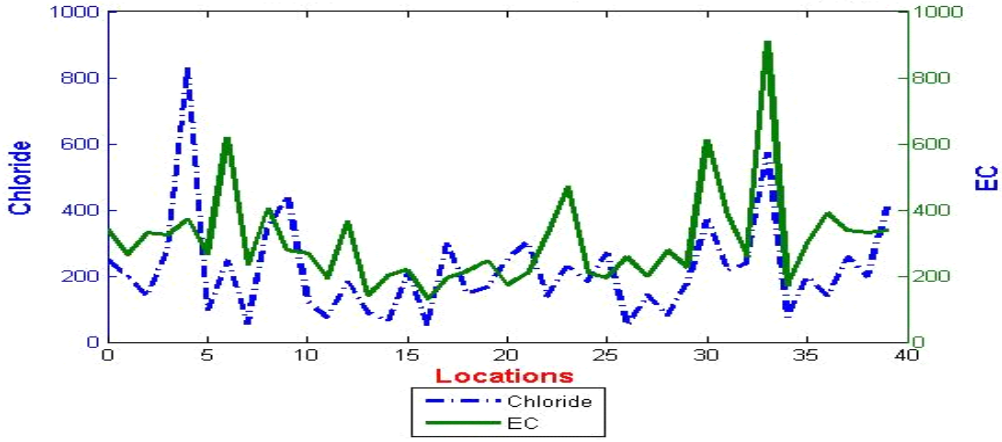

Figure 3b Correlation graph between chloride & EC in post-monsoon period

Cluster analysis of physico-chemical parameters: As large number of variables, observations, measurements and sites are involved, multivariate statistical analysis method in the form of Cluster Analysis has been used for data reduction and better understanding of the relationships between and among the variables and observations. Hierarchical Cluster Analysis (HCA) is a multivariate technique for classifying the objects of the system into categories or clusters based on their similarities and dissimilarities in the group [8]. In this study, cluster analysis was conducted and observations, variables, and groups of the sampled sites were compared and interpreted [9-10]. Cluster analysis of 40 monitoring sites based on the values of 18 physico-chemical factors identified two or multiple member clusters of sites in which groundwater quality and its changes show over than 96% - 98% similarity. Accordingly, forty site clusters were put into two logical clusters. Cluster analysis suggests three groundwater groups (**Figure 4**). EC seems to be a major distinguishing factor, which decreases with concentrations decreasing in all major ions following the order: G1, G2 & G3 (**Table 4**).

Dendrogram using Ward Method

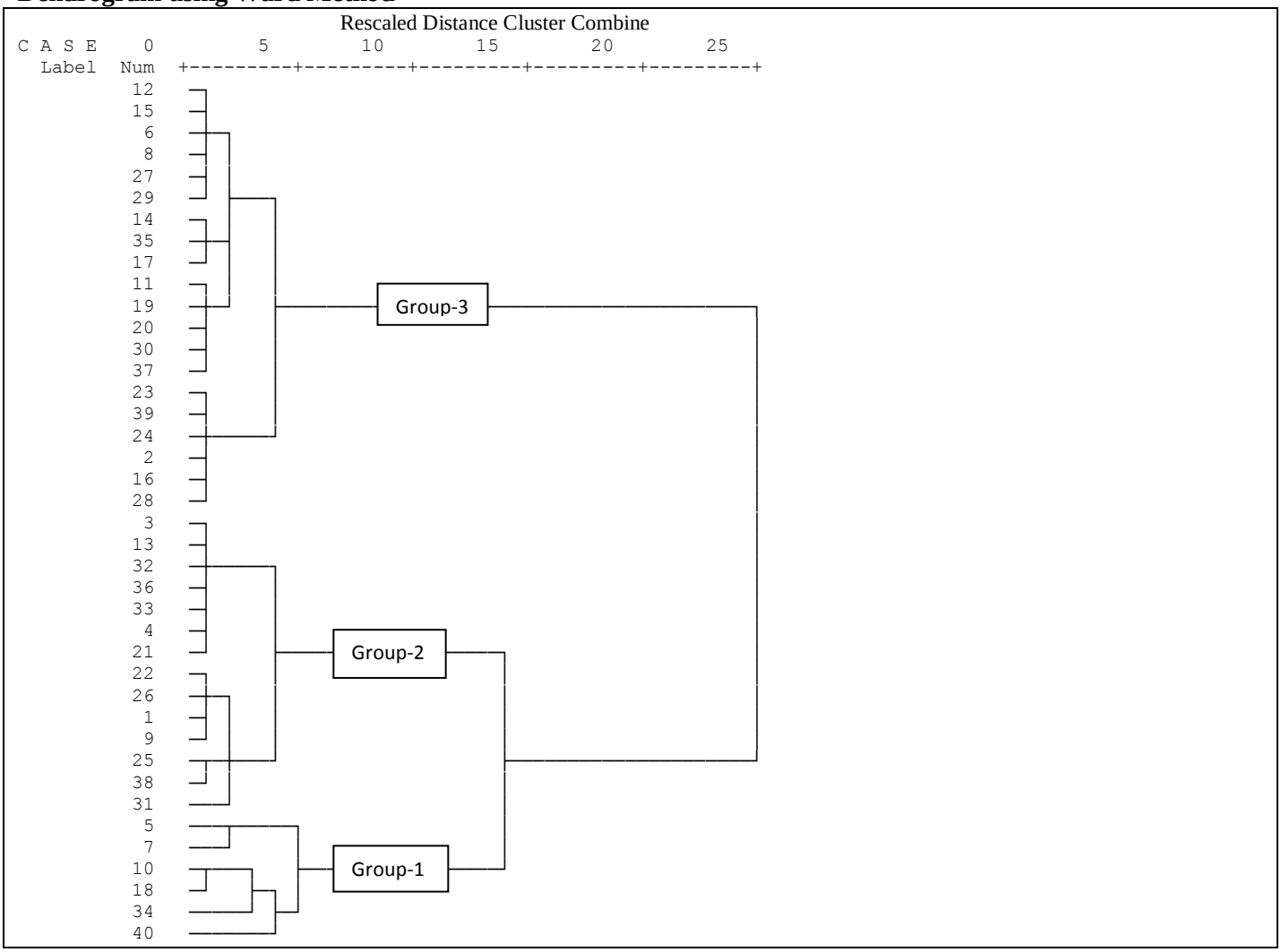

Figure 4 Cluster of different samples of Sanganer Tehsil in post-monsoon period

Group-1(G1) is composed of six samples S5, S7, S10, S18, S34 and S40 and concerns 15% of the water samples having EC 3248.67µmhos/cm which is the characteristic of high blended water (Mg^{2+}-Ca^{2+}-HCO_3^--Cl^-). Chloride content is too high with high concentration of bicarbonate.

Group-2(G2) is represented by 14 samples S1, S3, S4, S9, S13, S21, S22, S25, S26, S31, S32, S33, S36 & S38 and it occupies 35% of the water samples, where the EC is 1818.79 µmhos/cm which is the characteristic of blended water (Mg^{2+}-Ca^{2+}-HCO_3^--Cl^-). Chloride content is also high with respect to bicarbonate concentration.

Group-3(G3) includes 20 samples S2, S6, S8, S11, S12, S14, S15, S16, S17, S19, S20, S24, S27, S28, S29, S30, S35, S37, S39 and S40 and it occupies 50%. This type of water is relatively fresh with a mean EC of 946.30µmhos/cm, which is the characteristic of mixed water (Mg^{2+}-Ca^{2+}-HCO_3^--Cl^-). This group is basically bicarbonate and chloride dominated and it also has low concentration of sulphate.

Table 4 Mean parameter values of the three principle groups determined from HCA

GROUP	EC (µmhos/cm)	pH	HCO_3^- (mg/L)	CO_3^{2-} (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)
G1 (n=6)	3248.67	7.99	382.00	34.33	98.47	49.28	468.67	106.67	329.00	2.50
G2 (n=14)	1818.79	8.34	250.43	17.43	68.03	35.28	248.50	55.93	153.79	3.36
G3 (n=20)	946.30	8.33	305.60	24.40	66.96	20.18	138.30	45.85	133.80	3.35

Most of the samples were classified in Group I with good correlation between SO_4^{2-}, Ca^{2+}, HCO_3^-, TH, Cl^- & Na^+ with EC and TDS. Group II & III with only one parameter TDS & EC respectively as shown in **Figure 5**. The possible salt combinations $CaSO_4$, NaCl and mixed Ca^{2+}-Na^+-HCO_3^- are probably derived from weathering of rock salts and irrigation return flow.

Dendrogram using Ward Method

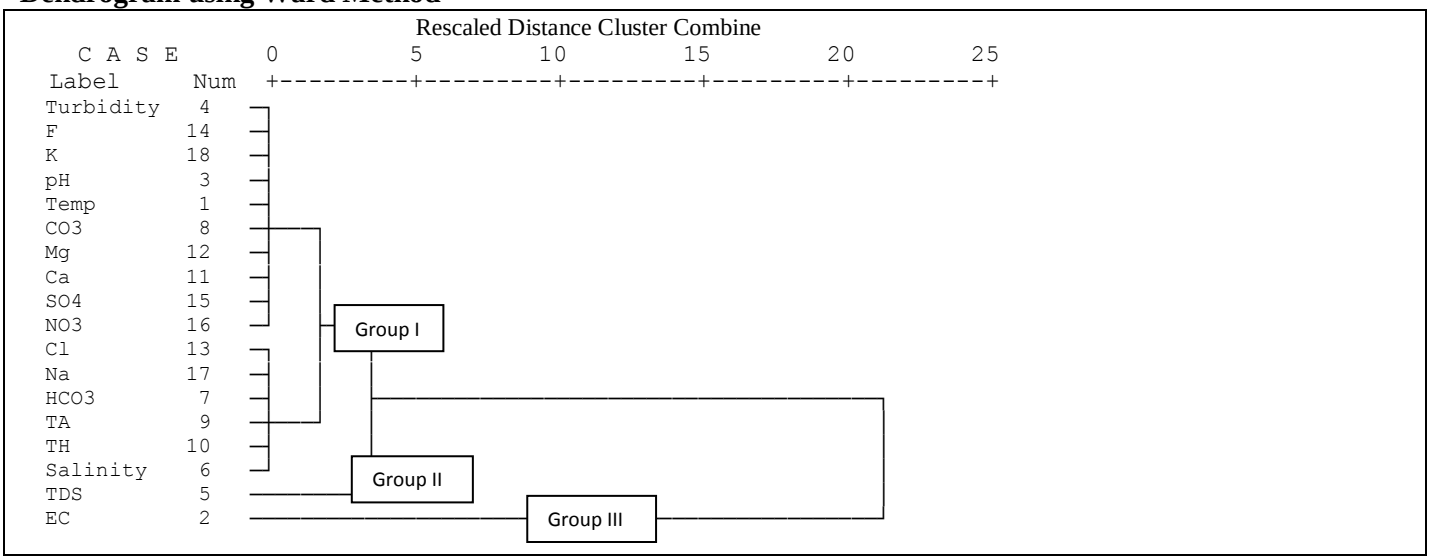

Figure 5 Groundwater grouping with respect to their physico-chemical parameters

Conclusions

It is found that most of the groundwater samples are above safe limits for drinking purposes. In addition, most of irrigation indices of the sampled water fall above the permissible levels indicating unsuitable water quality for irrigation. The samples from the study area classified in three major water types by HCA analysis as mixed water, blended water and highly blended water. In groundwater samples, EC seems to be a major factor which is the characteristic of blended water (Mg^{2+}-Ca^{2+}-HCO_3^--Cl^-). Chloride content is high with respect to bicarbonate concentration. However, fluoride levels in some samples do raise questions about potable drinking water. Hydrochemical analyses also indicate that parameters in some samples fall above the recommended limits of World Health Organization and thus less suitable or unsuitable for irrigation and domestic purposes.

Acknowledgement

The authors are thankful to Er. H. K. Solanki, Assistant Professor, National Institute of Rural Development and Panchayati Raj (Ministry of Rural Development, Govt. of India), Jaipur for his valuable suggestions.

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Publication History
Received 27th Oct 2015
Revised 16th Nov 2015
Accepted 04th Dec 2015
Online 30th Dec 2015