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Multivariate Statistical Analyses of Physicochemical Parameters in Groundwater Samples of Borinala Watershed of Aurangabad District, Maharashtra, India

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Abstract

The present study was carried out to evaluate the current status of groundwater samples collected from Borinala watershed of Aurangabad district. A total of 23 samples were collected and analyzed for the determination of various physicochemical parameters. The results of the present study established that some of the groundwater samples show slightly high pH (8%), TDS (4%), total hardness (4%), magnesium (4%) and bicarbonate (4%). This degradation of water quality occurred due to the agricultural practices. The order of mean levels of various physico-chemical parameters was found to be HCO_3 > Cl > Ca > Na >Mg. The correlation study revealed the strongest correlation was observed between conductance and sodium (r= 0.980). Multivariate analysis in terms of principle component analysis and cluster analysis furnished information about the sources of various parameters in groundwater samples. Therefore there is need to preserve and protect the precious groundwater resources as well as a continuous monitoring of groundwater resources is needed to know the quality water.

1. INTRODUCTION

Water is essential to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of human body (Buchholz, 1998). Water is also a vital resource for agriculture, manufacturing, transportation and many other human activities. Despite its importance, water is the most poorly managed resource in the world (Fakayode, 2005) Groundwater is the major source of drinking water in both urban and rural areas. The importance of groundwater for the existence of human society cannot be overemphasized. Besides, it is an important source of water for the agricultural and industrial sector. Till recently it had been considered a dependable source of uncontaminated water. Groundwater crisis is not the result of natural factors. It has been caused by human actions. Much of ill

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health which affects humanity, especially in the developing countries can be traced to lack of safe and whole some water supply. It is estimated that 80% of domestic needs in rural areas and 50% in urban areas is met by ground water. India's total replenishable groundwater has been estimated at 431.8 km3 by the Central Statistical Organization. The average level of groundwater development in India is 32%, although some states have exploited their resources to a much greater extent (94% in Punjab, 84% in Haryana, 60% in Tamil Nadu, 64% in Lakshadweep, 51% in Rajasthan). 85% of ground water extracted is used for irrigation purposes and 15% for Industrial and domestic purposes. Reciprocally, as much as 70 to 80% of India's agricultural output may be groundwater dependent. The dynamic balance in the aquatic ecosystem is upset by human activities thereby resulting in its pollution which is manifested dramatically as fish kill, offensive odor, color, and taste, and unchecked aquatic weeds. Fresh, clean water has thus become a scarce commodity. The quality of groundwater depends on various chemical constituents and their concentrations, which are mostly derived from the geological data of the particular region but industrial and municipal wastes also contribute significantly towards it. In fact, high rate of exploration, inappropriate dumping of solid and liquid wastes and lack of strict enforcement of law have caused the deterioration of groundwater quality (Garg et al, 1999; Sukhdev et al, 2010; Phiri et al, 2005, Kumar m et al, 2009; Mondal et al, 2005; Kaur and Malik, 2005; Tariq, 2014). The determination of physicochemical parameter has established role in evaluating the quality of groundwater, which is why these parameter have also been duly focused on. The chemical composition of water has evolved much interest during the last few decades because of several factors. The quality of groundwater is deteriorating mainly due to anthropogenic activity, irrigation return flow, excessive utilization of chemical fertilizers, municipal waste, unhygienic practices, septic tank effluent and landfills leachate (Srinivasmoorthy et. al., 2011). The water resources monitoring and assessment would be very useful for the sustainable development and safety under extreme events (Golekar et al, 2017). Naturally, ground water contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer; they are referred to as dissolved solids. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer. The quality of ground water depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region (Aher, 2012; Reddy et al, 2012). On overall, the quality of drinking water may cast hazardous effects on the health of human beings and this quality is monitored in terms of various parameters. All these parameters must be within safe limits; otherwise their presence at enhanced levels will be quite harmful to humans (Shymala et al, 2008;Kara et al, 2004; Gupta et al, 2009). The objective of present study was therefore to determine the quality of groundwater in terms of physico-chemical parameters.

1.1 Study area

The study area lies in vaijapur taluka of Aurangabad district, covers an area of 284.98 sq km contains 25 villages and lies between latitudes 19°45′05'' to 20°50′01'' N and longitudes 74°45′00'' to 74°55′05'' E (Fig.1) in the Survey of India topographical maps (46L/16 and 46I/13). The area is mainly drained by Bori nala viz the westernmost significant tributary of the Shivna river and is which rises above Hilalpur village on the low water divide separating it from the Manyad river, near Kolhi village where the Aurangabad- Vaijapur road crosses the Bori is located the Kolhi Project, after passing by Borsar, Bhaigaon, Parsoda and Karanjgaon it turns and flows southwards to join the Shivna river above Katepimpalgaon below the confluence of the Dheku river. The climate of the study area is hot summer and a general dryness throughout the year except during the south west monsoon season with mean minimum temperature of 10.3°C in winter and mean maximum temperature of 39.8°C in summer. The average rainfall is 634.23 mm and agriculture is the main source of livelihood. The major part (95%) of the borinala watershed constitutes a sequence of basaltic lava flows (Deccan Trap) while alluvium occupies a small portion. There are two distinct hydrogeological units' viz fissured formations (different units of basaltic lava flows) and porous formations (isolated patches of alluvial deposits). The occurrence and movement of ground water is controlled by variation in water bearing properties of these formations.

2. METHODOLOGY

The present study was designed to evaluate the contents of physico chemical in the groundwater samples, Samples were collected from wells as shown in (Fig. 1.) Groundwater samples were collected, preserved, and analyzed as per standard methods (APHA, 1998). A total of 23 samples were collected were analyzed for physicochemical parameters as pH, total dissolved solid (TDS), total hardness, alkalinity, calcium (Ca), magnesium (Mg), sulfate (SO_4), carbonate (CO_3), bicarbonate (HCO_3) and chloride (Cl), the pH and electrical conductivity (EC) EC was analyzed immediately after sampling, among the analyzed ions, sodium (Na) and potassium (K) were determined by using flame photometer.

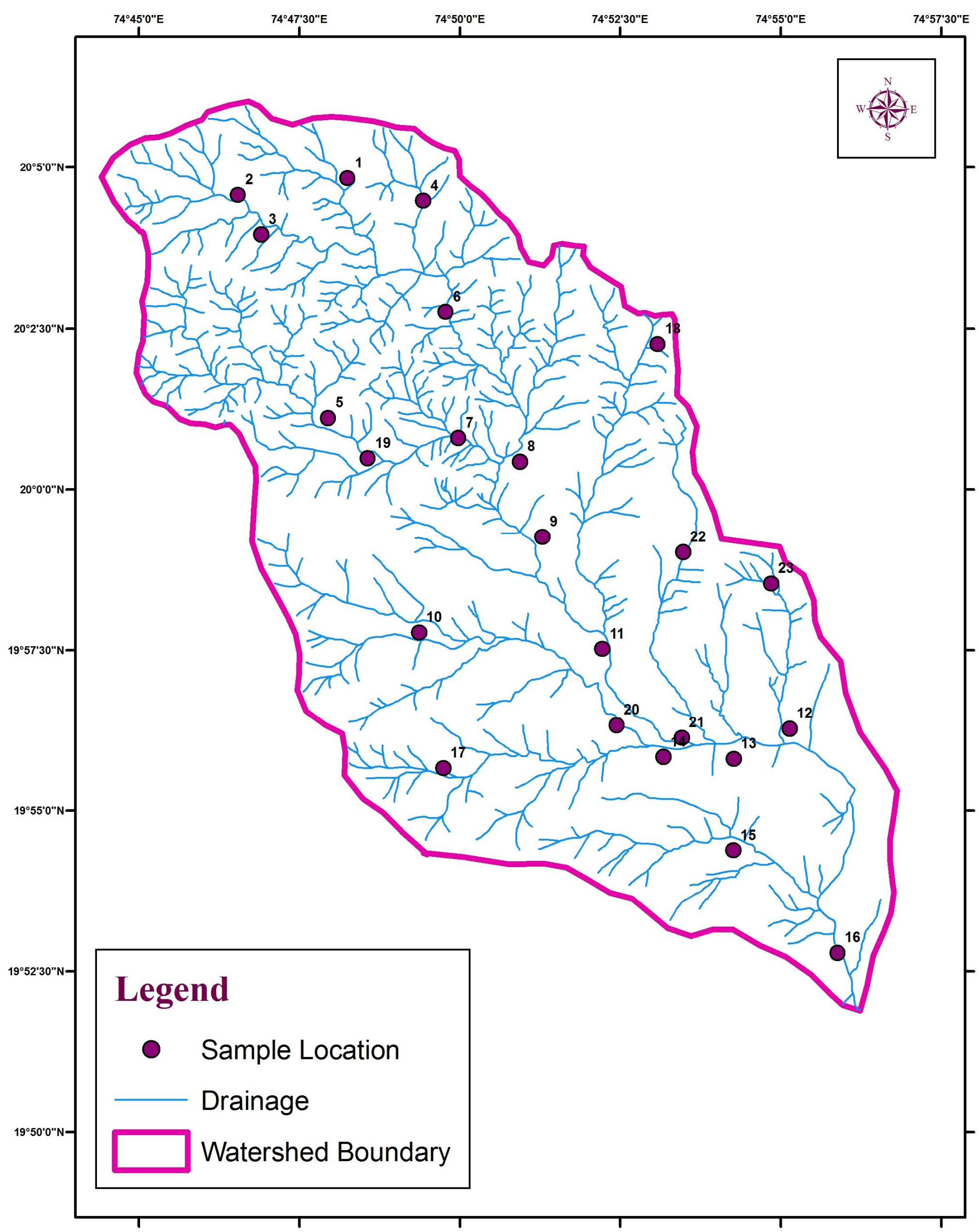

Fig.1: Location map of the study area

Total hardness, calcium, magnesium, bicarbonate and chloride were analyzed by volumetric methods and sulfates were estimated by using the colorimetric method. The suitability of groundwater was evaluated by comparing the values of different water quality parameters with those of the World Health Organization (WHO 2004) and Indian standard specification (ISI 1993) guidelines values for drinking water.

Table 1: Basic statistics for the physico chemical parameter

Parameter	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	7.01	9.27	7.7213	0.64624	0.916	0.035
EC	360.00	4360.00	1088.3913	828.24375	3.023	11.297
TDS	234.00	2834.00	707.5652	538.33504	3.023	11.296
TH	112.00	1164.00	346.0870	208.74994	2.888	10.869
Ca	14.00	115.00	70.3043	28.81672	-0.456	-0.553
Mg	6.00	217.00	41.2609	41.97534	3.565	15.004
Na	13.60	122.00	61.7000	31.08715	0.492	-0.642
K	0.10	138.00	6.8087	28.62789	4.780	22.893
CO_3	0.00	72.00	11.4783	21.27925	1.691	1.826
HCO_3	12.00	708.00	218.4348	132.05365	2.367	8.547
Cl	26.00	234.00	129.0435	58.95104	0.103	-0.798
SO_4	19.00	289.00	59.9983	55.63331	3.468	13.851

(All parameter in mg/L, except pH and EC in µ/cm)

2.1 Statistical Data Treatment.

The data obtained from physico-chemical parameters, in the groundwater samples, were cast into tables and figures and was also processed for the evaluation of various statistical parameters, like mean, standard deviation, and so forth, that are used to measure the distribution and central tendency of the measured data set. Box diagram furnished a clear depiction of the data distribution. Correlation coefficient matrix was determined to know about the interrelationship among the various measured parameters. Multivariate statistical analysis was also carried out in terms of factor analysis and cluster analysis to trace the sources of various parameters in the water samples.

3. RESULTS AND DISCUSSION

3.1 Distribution of Physicochemical Parameters among the Groundwater Samples.

The pH value of most of the groundwater samples in the study area varies from 7.01 to 9.27, with mean value of 7.7 which indicates that the groundwater in the study area is slightly alkaline in nature and 8% of the samples shows slightly high pH. The EC of the groundwater is varying from 360 and 4360 µ/cm with an average value of 1088.39 µ/cm and 17 % samples crosses the maximum permissible limit given by ISI (1993). In the study area the TDS value varies between a minimum of 234 mg/L and a maximum of 2834 mg/L with an average value of 707.56 mg/L, indicating that most of the groundwater samples lie within the maximum permissible limit. The total hardness is varying from 112 to 1164 mg/L with an average value of 346.08 mg/L. relatively, the higher concentration of total hardness observed is 1164 mg/L from the groundwater sample 22, except this groundwater of the entire study area lies within the maximum permissible limit prescribed by ISI (1993). Calcium concentrations are varying from 14 to 115 mg/L with an average value of 70.30 mg/L. The desirable limit of calcium concentration for drinking water is specified as 75 mg/L (ISI 1993) which shows that 52 % groundwater samples fall below desirable limit while 48 % of the samples beyond the desirable limit but within the maximum permissible limit. The values of magnesium from groundwater ranged between 6 to 217 mg/L, with an average value of 41.26 mg/L. The maximum permissible limit of Mg Concentration of drinking water is specified as

100 mg/L (ISI 1993) and 150 mg/L (WHO 2004). As per specification 43% samples falls under below desirable limit, a 52% sample are above desirable limit but with the maximum permissible limit and one sample (Sample number 22) exceeds the ISI limit as it shows a value of 217 mg/L. The sodium (Na) content of the groundwater ranged from 13.6 to 122 mg/L with an average value of 61.7 mg/L, the maximum permissible limit of sodium is 200 mg/L and it reveals entire samples are within the permissible limit of WHO and ISI. Concentration of K is observed between 0.1 and 138 mg/L from the groundwater with an average value of 6.80 mg/L. The value of CO_3 is observed from 0 to 72 mg/L, while the value of HCO_3 is observed from 12 to 708 mg/L with an average value of 218.43 mg/L, The sulfate concentration in the study area ranges between 19 and 289mg/L with an average value of 59.99 mg/L, indicating that all samples fall within the maximum permissible limit prescribed by ISI (1993). In the study area, the concentration of chloride is between 26 and 234 mg/L with an average value of 129.04 mg/L and all samples are within the limit prescribed by ISI (1993).
The results of the present study established that some of the groundwater samples shows slightly high pH (8%), TDS (4%), total hardness (4%), magnesium (4%) and bicarbonate (4%). This degradation of water quality occurred due to the agricultural practices.

Table 2: Groundwater samples of the study area exceeding the permissible limits prescribed by WHO (2004) and ISI (1993) for drinking purpose.

Sr No.	Water quality parameters	WHO International Standards 2004		Indian Standard (ISI 10500, 1993)		Range in the study area
		Most desirable limit	Max. allowable limit	Highest desirable	Max. permissible	
1	pH	6.5	8.5	6.5-8.5	6.5-9.5	7.01-9.27
2	EC	1500	-	-	-	360-4360
3	TDS	500	1500	500	2000	234-2834
4	TH	100	500	300	600	112-1164
5	Ca	75	200	75	200	14-115
6	Mg	50	150	30	100	6-217
7	Na	-	200	-	200	13.6
8	K	-	12	-	-	122
9	CO_3	-	-	-	-	0-72
10	HCO_3	-	-	200	600	12-708
11	Cl	200	600	250	1000	26-234
12	SO_4	200	400	200	400	19-289

3.2 Basic Statistics for Physicochemical Parameters of Groundwater Samples.

The data corresponding to the basic statistics for the physico-chemical parameters of the groundwater samples from study area was presented in Table 1, in terms of minimum, maximum, mean and S.D. The symmetry parameters for the data, that is, skewness and kertosis, are also enlisted in the table. The order of mean levels of various physico-chemical parameters was found to be HCO3 > Cl > Ca > Na >Mg. The distribution of various parameters is also depicted in terms of box plots shown in Figure 2.

3.3 Correlation Coefficient Matrix for Physicochemical Parameters of Groundwater Samples.

In order to trace the relationship among the various physico-chemical parameters, the correlation coefficient matrix was evaluated and presented in Table 3. The r values were found to be significant at level 0.01 and 0.05 levels (2-tailed). The strongest correlation was observed between conductance and sodium (r= 0.980) another significant correlation was observed between sodium and calcium (r=0.947), K and Mg (r=0.638), calcium and HCO3 (r=0.834), magnesium and SO4 (r=0.859) bicarbonate and chloride (r=0.836). The correlation coefficient matrix for the groundwater samples from study area evidenced strongest positive correlation between sodium and chloride with r values of 0.0.951. Some of the physico-chemical parameters were also found to be significantly negatively correlated evidencing, that with the increase in concentration of one parameter, the concentration of another parameter simultaneously decreased; that is, K was significantly negatively correlated with total hardness with r values of −0.017, CO3 was significantly negatively correlated with total hardness r values of −0.101. pH was significantly negatively correlated with total hardness (r= -0.124), HCO3 (r= -0.26).

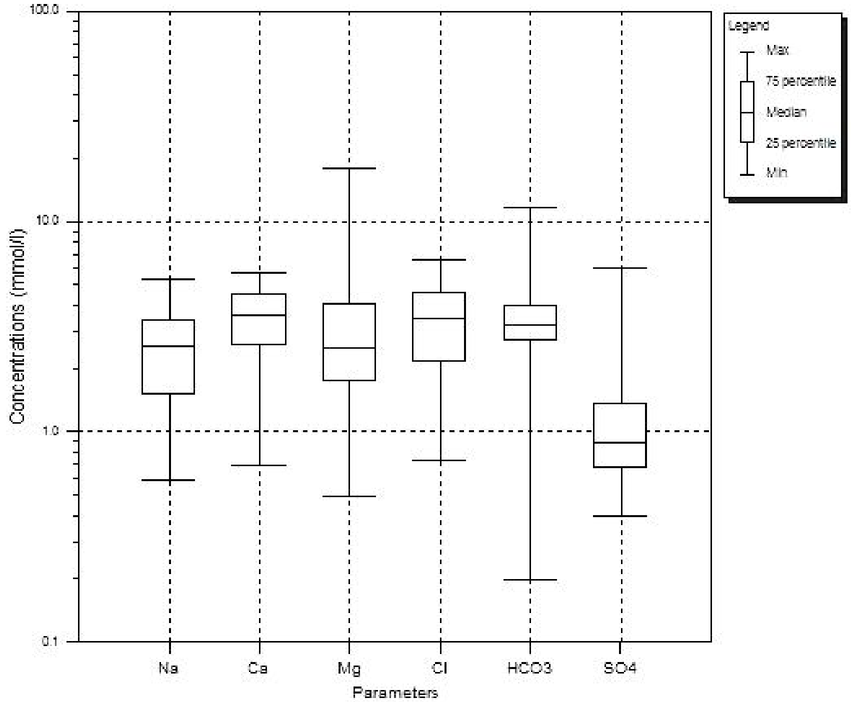

Fig. 2: Box plot for parameters from study area

Table 3: Correlation coefficient matrix for the groundwater samples from study area

Parameter	pH	EC	TDS	Na	K	Ca	Mg	TH	CO_3	HCO_3	SO_4	CL
pH	1											
EC	.224	1										
TDS	.223	1.000**	1									
Na	.283	.980**	.980**	1								
K	.047	.617**	.617**	.633**	1							
Ca	.323	.929**	.929**	.947**	.352	1						
Mg	.033	.632**	.632**	.561**	.638**	.413	1					
TH	-.124	.165	.166	.045	-.017	.060	.385	1				
CO3	.784**	.437*	.437*	.457*	.168	.483*	.253	-.101	1			
HCO3	-.026	.909**	.909**	.884**	.568**	.834**	.600**	.270	.097	1		
SO4	.114	.666**	.666**	.654**	.755**	.477*	.859**	.348	.238	.588**	1	
CL	.264	.958**	.958**	.951**	.514*	.937**	.557**	.043	.492*	.836**	.548**	1

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

3.4 Multivariate Statistical Analysis of Physicochemical Data.

The sources of various physicochemical parameters in various water samples were traced in terms of multivariate analyses, that is, factor loading and cluster analysis. Varimax normalized factor loading for twenty three samples from study area (Table 4). Factor 1 with a % total variance of 59.82 received major contribution from conductivity, sulfate, total hardness and magnesium. A 14.01% total variance was associated with factor 2. Among the major contributors of this factor pH and CO_3 were included. Na and chloride were present as major contributors of factor 3 that enjoyed a cumulative % variance of 82.38.

The cluster analysis of the data for the physico-chemical parameters of groundwater samples is presented in Figure 3. Single linkage method was used for the extraction of clusters that were depicted as a function of linkage distance. For samples from, the most significant primary cluster was formed by conductance and total hardness within a linkage distance of 5. Another primary cluster was formed between TDS and sulfate, sodium and chloride, thereby supporting the data of factor analysis where both parameters were major contributors of a single factor. These primary clusters were linked together to form a secondary cluster within linkage distance of 5 and 10. Potassium here exhibited an isolated role.

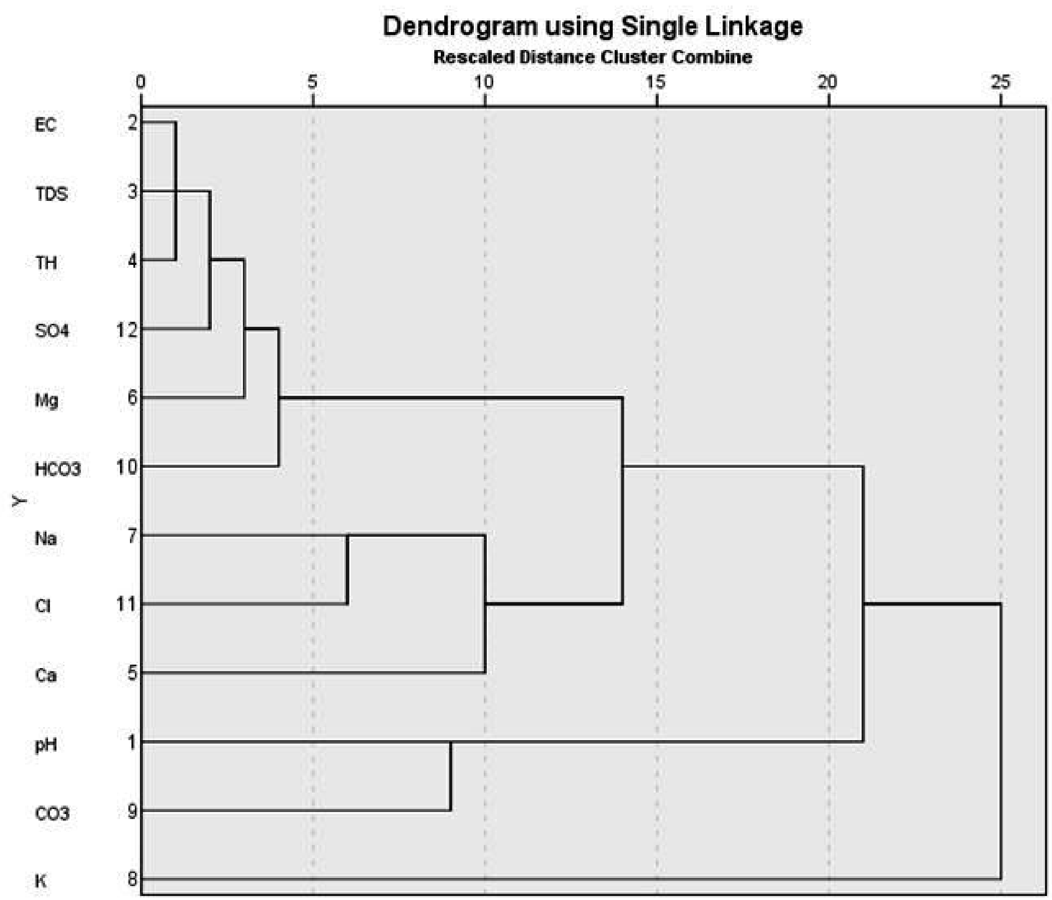

Fig. 3: Cluster analysis for parameters from study area

Table 4: Varimax normalized factor loading for various parameters

	Factor 1	Factor 2	Factor 3
pH	.264	.702	.275
EC	.990	.005	-.131
TDS	.990	.005	-.131
TH	.978	.083	-.150
Ca	.638	-.244	.234
Mg	.897	.225	-.313
Na	.703	-.359	.443
K	.163	-.310	.138
CO_3	.475	.787	.362
HCO_3	.883	-.280	-.288
Cl	.759	-.362	.522
SO4	.937	.137	-.196
Total	7.719	1.682	1.025
% of variance	59.822	14.018	8.543
Cumulative %	59.822	73.840	82.383

Table 5: Comparison of mean levels with ISI (1993) standards

Parameter	Mean	ISI (1993)
pH	7.7	6.5-8.5
TDS (mg/L)	707.56	2000
TH (mg/L)	346.08	600
Ca (mg/L)	70.30	200
Mg (mg/L)	41.26	100
HCO3 (mg/L)	218.43	500
Cl (mg/L)	129.04	1000
SO4 (mg/L)	59.99	400

A comparison of mean physico-chemical parameters of the groundwater samples collected from study area ISI (1993) standards is depicted in Table 5. The mean pH values observed was 7.7, which were well within the limits prescribed by ISI (1993), similarly the mean TDS, total hardness, calcium, magnesium, bicarbonate, chloride and sulfate values were well within the limits given by ISI (1993).

4. CONCLUSION

The results of the present study established that some of the groundwater samples show slightly high pH (8%), TDS (4%), total hardness (4%), magnesium (4%) and bicarbonate (4%). This slightly degradation of water quality occurred due to the agricultural practice. Thus all the above results confirmed that groundwater quality of the is slowly degrading and in near future the groundwater resource will be become polluted if appropriate strategies are not adopted so there is urgent need to preserve and protect the this valuable groundwater resources as well as a continuous monitoring of groundwater resources is needed to know the depth and quality of groundwater.

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