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Wqı And Multivariate Statistical Analysis Of Groundwater Quality Assessment For Domestic Purpose İn Mulbagal Taluk, Kolar District, Karnataka, India

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Abstract

The Mulbagal taluk has been chosen for ongoing research and large-scale groundwater extraction meets the requirements for domestic and irrigation water. The region is one of the worst drought-hit areas in Karnataka, where demand for groundwater has increased in recent years due to demographic pressures, urban sprawl, declining rainfall and a lack of permanent rivers. Therefore, this study was directed to evaluate the appropriateness of domestic groundwater by validating water quality standards. The authors have taken51 groundwater samples were collected in the field area, including pH, electrical conductivity (EC), total dissolved solids (TDS), carbonates (CO_3), bicarbonates (HCO_3), chlorides (Cl), sulfates (SO_4), nitrate (NO_3), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K) and total hardness (TH). The obtained values are used to characterize the suitability of groundwater quality for drinking purposes, and these values correlate with the WHO (2011) and BIS (2012) criteria. The Piper line graph confirms that most of the sample is of the NaCl type. The TDS classification indicates about ¾ of samples are fresh water and 1/4 is brackish water. The valuation of groundwater quality is made using the WQI, and it is found that the water in some locations are unsuitable for drinking purposes.

Keywords: Hydrogeochemistry, GIS and Remote Sensing, WQI, correlation matrix.

Introduction

Groundwater is not found in one pervasive aquifer, but in thousands of regional systems and aquifer complexes with the same features. Understanding the evolution of groundwater quality is essential for arid and semi-arid regions (Abazar Mostafaei, 2014). Groundwater pollution in cityenvironment is a serious problem and is multifaceted by a quantity of possible causes of pollution (Jayaprakash et al., 2008). In addition, the study area is subject to fast population growth, which leads to extreme water consumption, affecting the obtainability of fresh water and its quality. In arid and semi-arid regions, knowledge of the formation, recharge and regeneration of groundwater is especially important due to fluctuations in rainfall and insufficient surface water (M. Vasanthavigar et al., 2010). The quality of groundwater depends on the quality of recharge water, rainfall, surface water and the biochemical process of groundwater. Temporary changes in the origin and composition of make-up water, hydrological and anthropological variables can cause occasional changes in groundwater quality (Mimoza Milovanovic, 2007).High demand for water supplies, including groundwater, is forced by rapid industrialization and urban development, often resulting in their depletion and pollution. The stability of groundwater depends on different chemical elements, the concentration of which is mainly determined by the geological data of the area. Groundwater quality generally depends on recharge composition, water-soil interaction, soil-gas interaction, contacting rocks in the unsaturated area, retention period and groundwater response. Aquifer. (Freeze and Cherry, 1979; Hem, 1989).Therefore, in Mulbagaltaluk, attempts were made to separate groundwater, regional chemical composition of water using basic ionic chemical compounds. In this study, phase SA was made on the station using the Ward method (1963), which used the Euclidean distance as a match. The ward method uses different analyzes to estimate the distance among clusters and reduces the amount of the equal of two possible clusters. Ward's approach uses variation analysis to measure the distance among clusters and reduce the sum of the squares on each floor between two possible clusters. The Euclidean distance is usually the distance between the similarities between the two models, and the difference between the values of the modified sample (Abazar Mostafaei, 2014; Zhou et al., 2007).The WQI is a well-known technique that provides citizens and policymakers with a powerful tool to simplify their understanding of water quality(Oualid Bouteraa et al., 2019; Chauhan and Singh, 2010).

Study area

It is located geographically between latitude from 13° 01′ 30′′ to 13° 21′ 45′′ N and longitude from 78° 15' 15'' to 78° 35' 00'' E covering an aerial extent of 823 square kilometers. Topo sheet numbers 57K/7, 57K/8, 57K/11, and 57K/12 cover the entire area of the mulbagal taluk boundary.

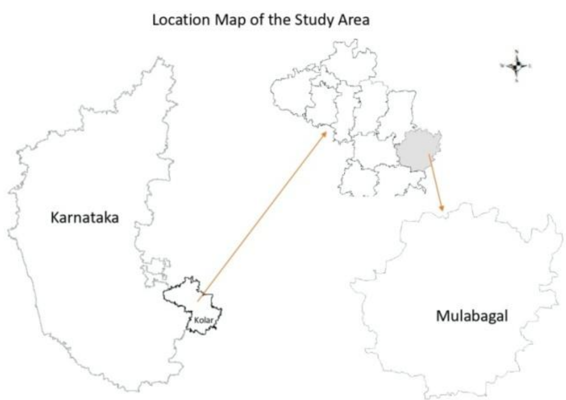

Figure 1. Location map of the field Area

The area selected for the research work is the frequent drought-prone area of Kolar District belonging to the Eastern end of Karnataka state. The Palar, North Pennar, and South Pennar are the main Non-perennial river basins that start flowing from NE and SE of Kolar District. The Mulbagal Taluk has small tributaries called mulbagilu kere and nangali and the water runoff is only during the monsoon season.It is connected to Kolar Taluka in the west, Srinivaspura Taluka in the northwest, Andhra Pradesh in the north and east and Bangarpet Taluk in the south.The common rock types appeared in the field(Fig. 1)are Dharwar schists Champion Gneiss Peninsular Gneissic Complex – Granites & Gneisses. Dolerite – Dykes Metabasalt(CGWB).

Materials and Methods

Groundwater sample analysis

To assess groundwater contamination, the authors were taken the sample of 51 groundwater mobilized from the study field. The samples are consisting of electrical conductivity (EC), pH, total dissolved solids (TDS), essential cations (calcium, magnesium, sodium, potassium) and ions (bicarbonate, carbonate, chloride, nitrate and sulfate), US APH 1995) Laboratory using standard methods.

Sites were selected for groundwater sampling to protection the wholefield area and more attention paid to the area where pollution is anticipated. Assumed ground pollution includes chloride, nitrate and fluoride. Therefore, more samples were collected in the field area where pollution is more expected. Groundwater samples were taken using pre-cleaned polyethylene containers. The results were reviewed in a letter with the WHO Drinking Water Quality (WHO 2011).The researchers were Arc GIS software are used to draw the contours of spatial distribution of physiochemical parameters which indicates the ions concentrated zones shown in the map (Fig. 2 and 3).

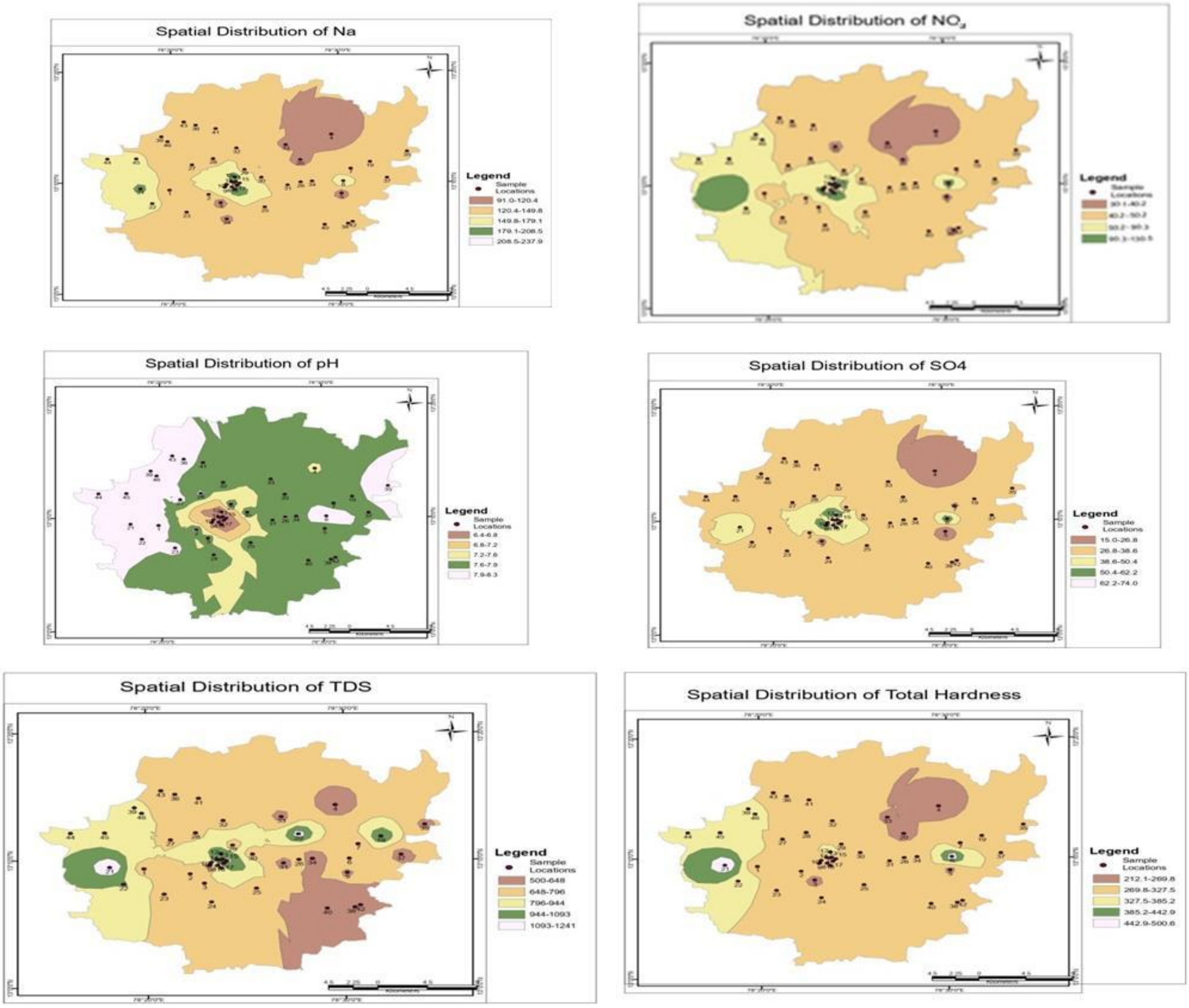

Figure 2. Spatial distribution of Na, NO_3, pH, SO_4, TDS, TH

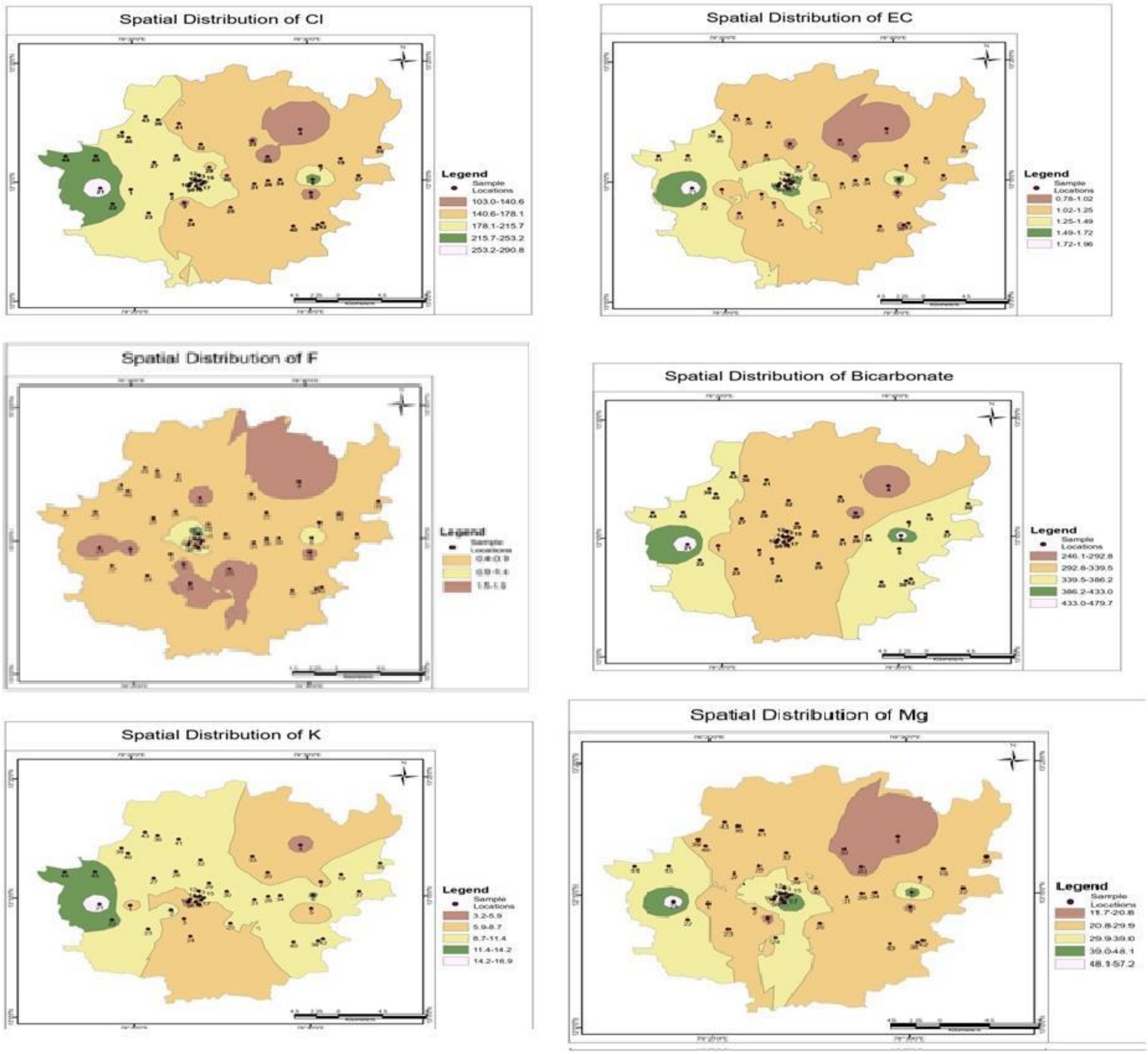

Figure 3. Spatial distribution of Cl, EC, F, HCO_3, K, Mg

Hierarchical cluster analysis and correlation matrix

Cluster analysis is a greatinstrument for hydro chemical research by combination water samples into geographically and hydrologically important groups to understand the hydrochemical processes taking place in the field (Guler et al., 2004; Singh et al., 2017; Kosha A Shah et al.,2017). Using the SPSS program, version 17.0 (SPSS, 2008). Multivariate statistical methods have been performed such as hierarchical cluster analysis (HCA) and correlation matrices for groundwater chemistry data. HCA results are useful for interpreting data and displaying patterns (Reghunath et al., 2002; Lin et al., 2012; Zhang et al., 2012; Guanxing Huang et al., 2013).

Water Quality Index (weighted arithmetic mean method)

Water Quality Index refers to the simple and efficient instrumentused worldwide to assess the appropriateness of drinking water (M Vasanthavigar et al., 2019; Jamil Siddique et al., 2020).In this study, the weighted average WQI method was used to determine the water quality in the study area. Weighted arithmetic mean WQI can be estimated using the following formula (Brown et al., 1972).

Step-1 Using the formula, calculate the unit weight (Wn) factor for the parameters.

$$Wn = \frac{K}{Sn} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

Where

$$K = \frac{1}{\frac{1}{S1}+\frac{1}{S2}+\frac{1}{S3}\ldots\ldots 1/Sn} = \frac{1}{\Sigma\, 1/Sn} \ldots\ldots\ldots\ldots \quad 2$$

S_n= Standard desirable value of n^{th} parameter

On summation of all parameters unit weight factors, W_n=1(unity)

Step -2 calculation of sub-index (Q_n) value

$$Qn = \frac{[(Vn - Vo)]}{[(Sn - Vo)]} * 100 \ldots\ldots\ldots\ldots\ldots\ldots \quad 3$$

Where

V_n= Mean concentration of n^{th} parameters

S_n= Standard desirable value of the n^{th} parameters

Vo= Actual values of the parameters in pure water (generally except for pH Vo=0 for all the parameters

$$QpH = \frac{[(VpH - 7)]}{[(8.5 - 7)]} * 100 \ldots\ldots\ldots\ldots\ldots\ldots \quad 4$$

Step-3 combining Step1 and Step2, to calculate overall WQI

$$\mathbf{WQI} = \frac{\mathbf{\Sigma WnQn}}{\mathbf{\Sigma Wn}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5$$

Results and Discussion

Chemistry of Ground Water

Determining groundwater quality is important because it is an important factor in determining suitability for drinking water, agriculture and industrial purposes (K. Arumugam et al., 2009). (Table 1) shows the parameters of physical chemistry which include statistical measurements such as minimum, maximum and average. EC values range from 720 to 2012 s / cm, average 1241 S / cm. The pH concentration of groundwater is 6.42 to 8.36, with an average of 7.73. This showed that the groundwater in the study area was mostly alkaline. TDS concentrations range from 450 to 1242.15 mg / L, with an average of 767.59 mg / L.

Table 1. Statistics of Physiochemical properties of groundwater in the study area

Parameters	Units	Maximum	Minimum	Mean	Median	standard deviation
pH		8.4	6.4	7.7	7.9	0.6
EC(us/cm)	µs/cm	2012.0	720.0	1242.0	1159.7	288.3
TDS	mg/l	1242.2	450.0	767.6	728.7	196.2
Ca	mg/l	126.0	65.3	84.2	82.8	15.6
Mg	mg/l	58.6	11.7	28.9	26.1	9.2
Total Hardness	mg/l	501.0	212.0	313.4	311.0	48.1
Bicarbonate	mg/l	480.0	246.0	340.2	336.2	37.7
Na	mg/l	243.0	91.2	142.0	133.7	27.9
K	mg/l	17.0	2.4	9.2	9.0	2.3
SO_4	mg/l	76.0	15.0	35.3	31.0	11.6
Cl	mg/l	291.0	103.0	181.1	170.7	35.8
F	mg/l	1.9	0.4	0.9	0.7	0.5
NO_3	mg/l	135.6	29.7	57.7	49.1	24.1
Zn	mg/l	0.9	0.2	0.4	0.3	0.2
Fe	mg/l	0.3	0.1	0.2	0.2	0.1
Mn	mg/l	0.3	0.2	0.2	0.2	0.1

Hydro-chemical facies

The geochemical evolution of groundwater can be traced back to Piper (1994) by focusing on the baseline and pine on three lines. Based on chemical analysis, ground water is divided into 6 stages. (Figure 4), I-CaHCO3 type, II-NaCl type, III mixed CaNaHCO3 type, IV mixed CaMgCl type, V-CaCl type, VI-NaHCO3 type. In the present study, approximately 55% of groundwater samples fall into the field of type II-NaCl, 35% of the samples fall into the category of type III-mixed CaNaHCO3, and 8% of groundwater samples fall into the field. I-CaHCO¬3 type and 2 ٪ IV compound CaMgCl type. From the plot, (Na and K) are higher than alkaline soils (Ca and Mg) and Cl surpasses other anions (minor acids).

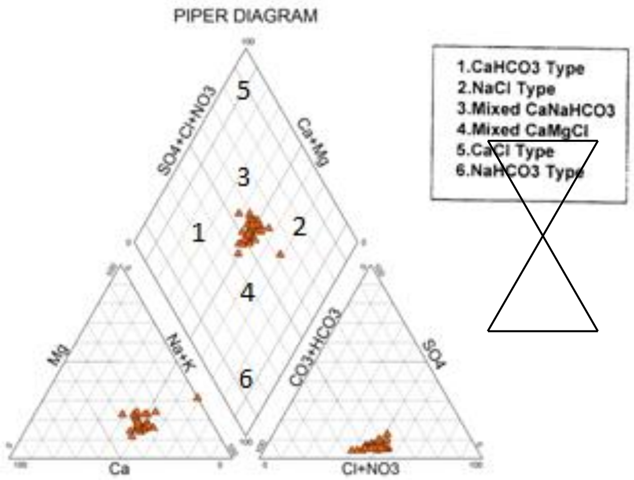

Figure 4. Piper diagram forhydrochemical facies

Important physiological properties such as concentration of vital ions (Ca, Mg, Na, K, CO3, HCO3, Cl, SO4, NO3,) and pH, EC, and aggregate solids (TDS) determined by domestic suitability and experience are shown in Table 1. The present study shows that the bulk of the large cation concentrations are in the Na + K> Ca + Mg order, while the groundwater contains anions in the order HCO3> Cl> NO3> SO4> CO3. The parameters of water quality with the limits recommended by the World Health Organization (WHO 2011) and the Bureau of Indian Standards (BIS 2012) are shown in (Table 2).

Table 2. Statistical data of physiochemical characteristics of groundwater as per drinking standard

Parameters		pH	EC(us /cm)	TDS	TH	Ca	Mg	F	Na	K	Cl	NO_3	SO_4
WHO (2011)	**WHO DL**	**6.5**	**1500**	**500**	**100**	**75**	**50**	**1**			**250**		**250**
	% of samples Exceeding Desirable Limits	98	16	98	96	88	96		0	0	76	0	0
	WHO PL	**8.5**		**1500**	**300**	**200**	**150**	**1.5**	**200**	**12**	**600**	**45**	**400**

	% of samples Exceeding Permissible Limits	0		0	62.7	0	0	21.56	10	2	0	64	0
	BIS DL	**6.5**		**500**	**200**	**75**	**30**	**1**			**250**	**45**	**200**
	% of samples Exceeding Desirable Limits	98		98	89	88	71	21.56			76	64	0
BIS (2012)	**BIS PL**	**8.5**		**2000**	**600**	**200**	**100**	**1.5**	**200**		**100 0**		**400**
	% of samples Exceeding Permissible Limits	0		0	13	0	0	21.56	10		0		0

pH and Electrical Conductivity (EC)

The pH demonstrates the strength of water that reacts to the acid or alkaline content of water (Hem J D, 1985). The pH range for drinking water is defined as 6.5-8.5 (WHO 2011; BIS2012). The pH values in the study area ranged from 6.42 to 8.36 (Table 1), averaging 7.73. This indicates that the groundwater in the study area is slightly alkaline. Basalts are the major rock types that make up the aquifers in the study area that can give alkalinity to groundwater, and may contribute to the increase in groundwater pH with anthropological functions such as mineral formation. (WHO 2011; BIS 2012) Most models (98%) are within the defined allowable range. EC concentrations in groundwater samples 2012 - 720 720S / cm Average range of 1241.9 / S / cm (Table 1) The preferred range of EC is 1500 µS / cm. The desirable limit of EC in drinking water is defined as 1,500 S / cm (WHO 2011). Approximately 16% of the samples exceed the acceptable limits of the study area indicating the presence of high salinity in groundwater. EC can be classified as type I (EC <1500 µS / cm), low salt, type II (EC 1500-3000 / S / cm), moderate salt reinforcement, type III (EC> 3000 S). / CM) Concentrations of salts are high (Sarath Prasanth SV 2012). The classification of EC is shown in (Table 3).

Table 3. Classification of EC concentrations in the study area

EC Classification	EC range	% of samples under each type
Category 1	EC<1500 µS/cm	84%
Category 2	EC 1500–3000 µS/cm	16%
Category 3	EC >3000 µS/cm	Nil

Total dissolved solids (TDS)and Bicarbonate (HCO_3)

TDS concentrations ranged from 450 to 1242.1 mg / L with an average value of 767.6 mg / L (Table 1). As per WHO (2011) and BIS (2012) standards, the maximum permissible limit for TDS in groundwater is 1500 mg / l. There are no over-the-counter models. (Freeze and Cherry, 1979) describes groundwater quality: I-TDS <1000 mg / l freshwater, II-TDS 1000-10,000 mg / l salt water, III-10,000-10000,000. have to do. Like salt water. 84.3% of the samples in the study area were classified as freshwater and 15.7% of the samples were categorized as brackish (Table 5). As per Davis and DeWeist (1966) classification, 2% of samples are desirable to drink, 82% of samples are permissible to drink, and 14% are effective for irrigation (Table 4).

Dissolved carbon dioxide, temperature, pH, cations and other dissolved salts depend on the concentration of carbonates in natural water. The concentration of bicarbonates in natural water is generally kept in the moderate range due to the effect of carbonate balance. Most surface streams were low at 200 mg / l carbonates and bicarbonates, but significantly higher in groundwater (S. Krishna Kumar 2015). Concentrations of bicarbonate range from 246 to 480 mg / l with an average of 340mg / l.

Table 4. Groundwater classification on the basis of TDS (Davis and DeWiest, 1966)

TDS Classification	Range	Percentage of Samples	Sample number
Desirable for drinking	<500	2%	8,9
Permissible for drinking	500-1000	82%	1,2,3,4,5,6,7,10,13,16,18,22,23,24,25,26,27,28, 29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,4 4,45,46,47,48,49,50,51

Useful for irrigation	1000-3000	14%	11,12,14,15,17,19,20,21
Unfit for irrigation and drinking	>3000	Nil	Nil

Table 5. Classification of groundwater based on TDS (Freeze and Cherry, 1979)

TDS Classification	Range	Percentage of Samples	Sample number
Freshwater	<1,000	84.3%	8,9,1,2,3,4,5,6,7,10,13,16,18,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51
Brackish water	1,000-10,000	15.7%	11,12,14,15,17,19,20,21
Saline water type	10,000-1,00,000	Nil	Nil
Brine water type	>1,00,000	Nil	Nil

Total hardness (TH)

Total hardness differs from 212 to 501 mg / l on average to 313.4 mg / l (Table 1). Groundwater classification (Sawyer & McCarthy, 1967) is about 37.20% harder in groundwater samples in terms of total hardness (TH) and 62.70% of groundwater samples harder in nature (Table 6). According to WHO standards (2011), groundwater that goes beyond the maximum TH limit of 500 mg / L for drinking and the most desirable limit of 100 mg / L. 300 mg / l is considered the hardest. 96% of models exceed the desired limit. However, 62.7% of the samples go beyond the acceptable limit. Compared to the BIS standard, 89% of the models exceed the desired limits and 13% of the samples exceed the acceptable limits. Water hardness is prompted by the presence of alkaline earth elements like calcium and magnesium.

Table 6: Classification of groundwater based on total hardness (TH) (Sawyer and McCarty 1967)

TH Classification	Range	Percentage of Samples	Sample number
Soft	<75	---	------
Moderately Hard	75-150	---	------
Hard	150-300	37.20%	1,2,3,4,5,7,9,13,15,17,20,24,25,26,

			29,30,31,32,33
Very Hard	>300	62.70%	6,8,10,11,12,14,16,18,19,21,22,23, 27,18,34,35,36,37,39,40,41,42,43, 44,45,46,47,48,49,50,51

Chloride (Cl)

Chloride concentrations vary between 103–291 mg / L with an average of 181 mg / L (Table 1). The Bureau of Indian Standards (BIS, 2012) and (World Health Organization 2011) and the preferred limit for chloride is 250 mg / l. In most places chloride concentrations were observed to be below the desirable limits in the study area. The chloride ion of the element chlorine is the most widespread natural form and the most stable in water. Groundwater can have many sources of chloride, such as weather, leaks, domestic and municipal waste (Sarath Prasanth, 2012).

Gibbs diagram

Gibbs layers are generally used to establish the relationship among the water system and the lithological properties of aquifers. The Gibbs map shows three different disciplines: rain dominance, evaporation dominance, and rock-water contact dominance (Gibbs, 1970). The ratio of Gibs Layers I (for pine) Cl / (Cl + HCO3) and TDS values for separately plotted groundwater samples II (for cations) was taken from Na / (Na + Ca). In (Figure 6) most models fall into rock-dominated fields with the predominance of evaporation on the Gibbs map. As a result, it became clear that the process of evaporation dominance was due to the dry and arid conditions prevailing throughout the region. Rock-dominated zone refers to the dissolution of silicate-bearing rocks in groundwater.

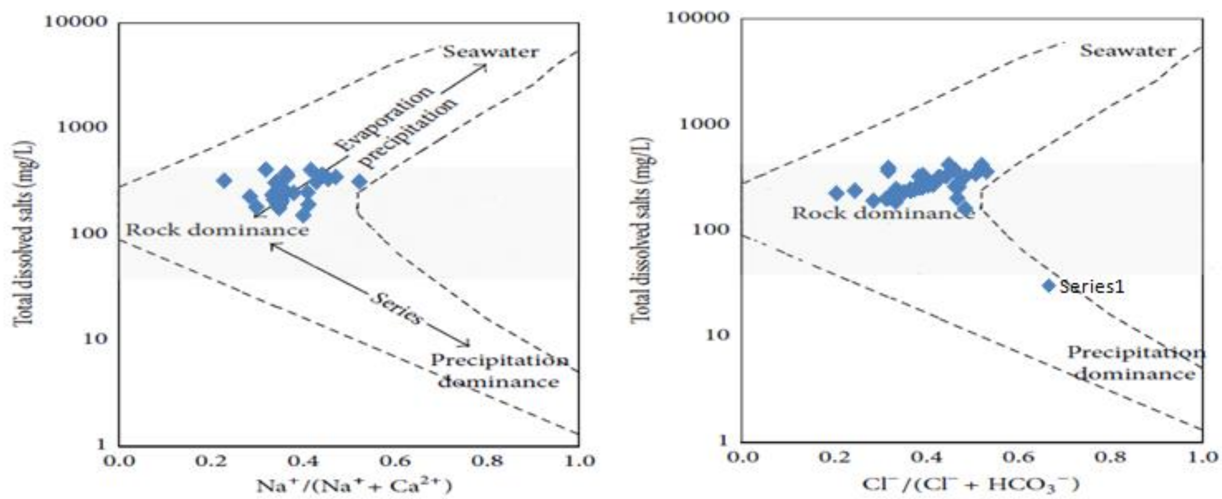

Figure 6. Gibbs diagram showing the process affecting groundwater chemistry

Sulfate (SO_4)

Concentrations of SO4 range from 15-76 mg / l to an average value of 35.2 mg / l. However, in the study area, the sulfate concentration in groundwater is within the permissible limits.

Nitrate (NO_3)

Nitrogen is initially corrected from the atmosphere and mineralized to ammonia by soil bacteria. Epidemiological evidence recommends that nitrate exposure is closely related to methemoglobinemia (blue baby syndrome), stomach, cancer, thyroid disease, and diabetes (Reza R et al., 2010; Aydin A, 2007). It has been found that NO_3 concentrations in the groundwaterare more than the maximum permissible limit in most of the locations in the study area. Theconcentration differs between 29.41-135.6 mg/l with an average value of 57 mg/l. Hence increased nitrogen contamination thus severely affects the availability of public drinking water and human health.

Calcium and magnesium (Ca and Mg)

Calcium concentrations in the study area ranged from 65.3 mg/l to 65.3–126 mg/l with an average of 84.1 mg/l and magnesium concentrations ranged from 11.7 to 24.3 mg/L with an average of 28, 8 mg/L.All water samples are within acceptable limits according to WHO (2011) and BIS (2012) standards.

Sodium and Potassium (Na and K)

Na ion concentration varies from 91.2–243 mg / l with an average value of 141.9 mg / l. In the study area, approximately 10% of the samples exceeded the permissible limit of WHO (2011) and BIS (2012) sodium concentrations. The K concentration varies between 2.4–17 mg / l with an average value of 9.1 mg / l. With the exception of one location, all samples had concentrations below the permissible limit of 12 mg / l (WHO 2011). High concentrations of potassium may be due to the leakage effect of industrial wastes and fertilizers used for irrigation purposes.

Correlation matrix

Contact matrices are used to understand the degree of correlation among different variables of physical and chemical parameters that affect the quality of groundwater in the study area. Statistical analysis of physicochemical parameters and concentrations of important ions was carried out to identify the relationships and variations between groundwater samples. Values are compiled by geochemical parameters for data discussion. This matrix was analyzed by cluster analysis using SPSS software (SPSS, 2008). The correlation between the two parameters is projected based on the value of the contact coefficient (r) in the XY scatter plot, and the overall correlation is said to be positive or negative. Because it is important to identify ions that control water chemistry, contact analysis has been acknowledged as a consistent and valuable statistical method for studying water quality (Box, 1978; Chapman, 1996; Vasant Madhav Wagh et al., 2019). A strong positive interaction refers to the same source of some ions, the origin and motion of which may be artificial or natural, while a weak interaction indicates that the ion sources are separated from each other (Islam et al. 2017).The variables showing the correlation coefficient (r> 0.7) are considered strong. Values of 0.5–0.7 (r) are moderately correlated and r <0.3 are weakly correlated(Vasant Madhav Wagh et al., 2019). (Table 7) shows the results of the correlation matrix for groundwater samples in the study area.

Table 7. Correlation matrix of physiochemical parameters of groundwater

Parameters	pH	EC	TDS	CO_3	HCO_3	Cl	SO_4	NO_3	Ca	Mg	Na	K
PH	1.00											
EC	-.26	1.00										
TDS	-.36*	.44**	1.00									
CO_3	.41**	-.17	-.24	1.00								
HCO_3	.35*	.30*	.14	.14	1.00							
Cl	-.23	**.52****	**.54****	-.08	**.62****	1.00						
SO_4	-**.55****	.25	.37**	-.28*	.19	**.68****	1.00					
NO_3	.34*	.29*	.37**	.14	.44**	**.50****	.06	1.00				
Ca	.23	**.57****	.16	.04	**.57****	.38**	.03	.27	1.00			
Mg	-.38**	**.55****	**.61****	-.13	**.53****	**.78****	**.57****	.35*	.27	1.00		
Na	-.52**	**.62****	**.54****	-.19	.25	**.65****	**.66****	.24	.22	**.82****	1.00	
K	.33*	.14	.48**	.24	**.58****	**.58****	.14	.59**	.26	.41**	.25	1.00

From the Table 7, these variables represent the moderate correlation of EC with the correlation with Cl (r = 0.52), Ca (r = 0.57), Mg (r = 0.55), and Na (r = 0.62). Inputs of Cl, Ca, Mg, and Na use excess compost, municipal wastewater, and over-exploitation by natural and human activities. Na and Mg have a strong correlation (r = 0.82) whereas pH has a negative correlation with all other variables.EC also shows moderate to negative correlation with other variables. Rest all having moderate to week correlation indicating the sources of ions are separate from each other.

Hierarchical Cluster Analysis (HCA)

Hierarchical cluster analysis is used based on common characteristics within classes and differences between different classes to classify groups or clusters of similar sites (Lattin et al., 2003; Vasant Madhav Wagh, 2019). The study of clusters involves a collection of multivariate approaches used to classify the true classes of data sets(Danielsson et al., 1999).In this study, the hierarchical tree diagram, called dendogramanalysis is developed using the Ward method applying squared Euclidean as a similar measureand the observations are shown in Table 8. The dendogram grouped water samples into four clusters (Fig. 7). At increasing levels of dissimilarity, the clusters are connected, and the horizontal axis in the dendogram denotes the connection distance between the clusters. About seven parameters are included in cluster I; they are PH, K, SO_4, Mg, CO_3, NO_3, and Ca. In cluster II; two parameters i.e. Cl and Na are included. HCO_3 alone forms a separate cluster (cluster III). EC and TDS form cluster IV. Whereas the cluster II and III combine to bring one single cluster i.e. HCO_3 groups with Na and Cl indicating that Na and Cl alter the values of HCO_3 in groundwater samples of the study area.

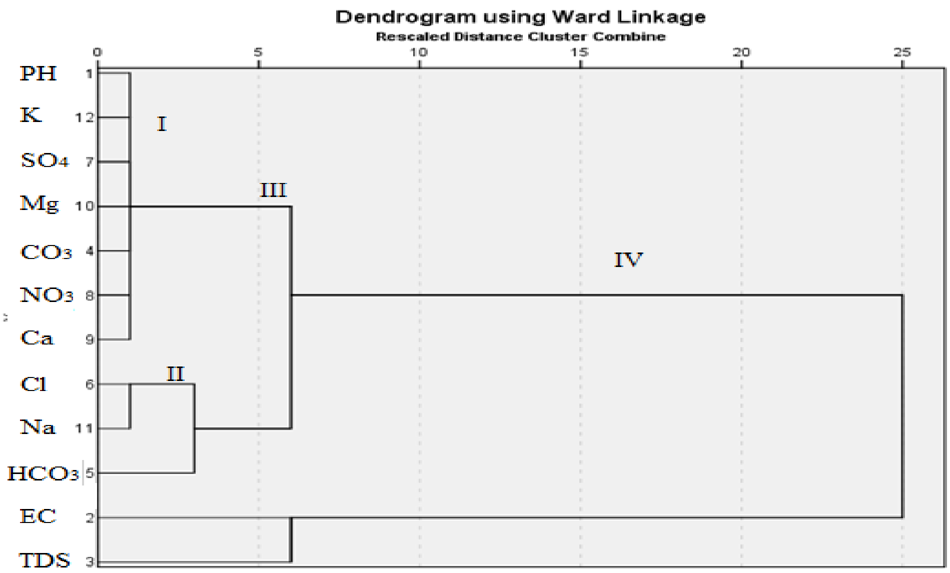

Figure 7. Dendogram for the grouping of groundwater concerning the physiochemical parameters

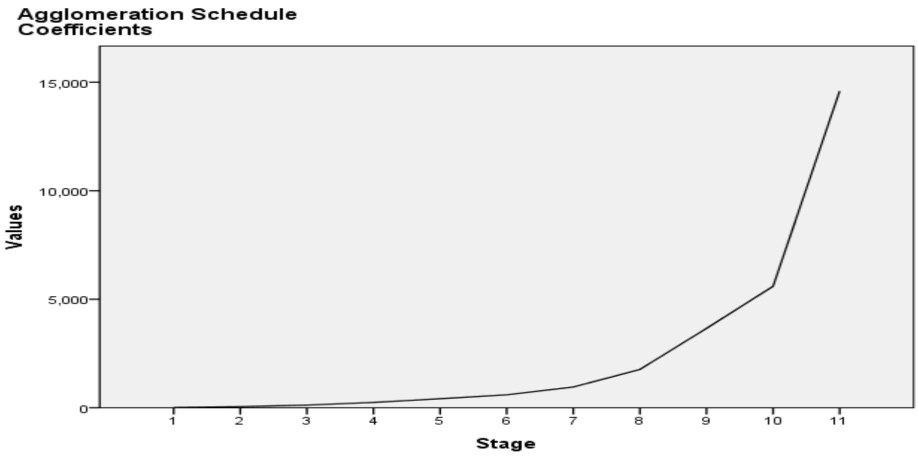

Figure 8. Agglomeration Schedule Coefficient indicating clusters of groundwater samples

According to the agglomeration schedule coefficient plot (Fig. 8), it is shown that there are four clusters formed. The first cluster starts at 11, the second cluster starts at 10, the third cluster starts at 8, and the next cluster starts at 7. In the case of rest, the proximity rate reduces.

Water Quality Index

WQI is an essential parameter for assessing groundwater quality and its appropriateness for drinking(Avvannavar and Shrihari,2008). WQI is defined as an evaluation system that gives the overall effect of individual water quality parameters on the overall quality of drinking water (Mitra and ASABE Member,1998). Groundwater chemistry is used as a method for forecasting water quality for drinking and irrigation purposes (Vasanthavigar Murugesan et al., 2010; Subba Rao, 2006). (Table 8) shows the WQI range and water type classification. Comparative weight (wi) is assigned to the water quality parameter based on its relative importance to the water quality for drinking needs(Table 9).

Table 8. WQI Classification

WQI Class	Water Quality Index	Water Quality Status
I	0-25	Excellent Water
II	26-50	Good Water
III	51-75	Poor Water
IV	76-100	Very Poor Water
V	>100	Unfit for Consumption

Table 9. Relative weight (wi) assigned for water quality parameters

Chemical parameters	WHO standards - 2011	(wi)	Relative weight Wi $= \frac{wi}{\sum_{i=1}^{n} wi}$
pH	7.5	4	0.114
EC	500	4	0.114
TDS	500	5	0.143
HCO_3	500	3	0.086
Cl	250	3	0.086
SO_4	250	4	0.114
NO_3	45	5	0.143
Ca	75	2	0.057
Mg	50	1	0.029
Na	200	2	0.057
K	200	2	0.057
		Σwi=35	Σwi=0.998

Table 10. WQI calculation for the sample collected at site no1

parameters	BIS Standards (Sn)	1/Sn	Σ1/Sn	K=1/(Σ1/Sn)	Wi=K/Sn	ideal value (Vo)	Mean Conc. Value (Vn)	Vn/Sn	Vn/Sn*100=Qn	WnQn
PH	8.50	0.1176	4.7063	0.2125	0.0250	7	8.36	1.3600	136.00	3.3997
EC	300	0.0033	4.7063	0.2125	0.0007	0	1.91	0.0064	0.64	0.0005
TDS	500	0.0020	4.70	0.2125	0.0004	0	124	2.48	248.43	0.1056

			63				2	43		
TH	300	0.0033	4.7063	0.2125	0.0007	0	501	1.6700	167.00	0.1183
Ca	75	0.0133	4.7063	0.2125	0.0028	0	126.0	1.6800	168.00	0.4760
Mg	30	0.0333	4.7063	0.2125	0.0071	0	53.20	1.7733	177.33	1.2560
Fe	0.3	3.3333	4.7063	0.2125	0.7083	0	0.08	0.2667	26.67	18.8872
Flouride	1	1.0000	4.7063	0.2125	0.2125	0	0.89	0.8900	89.00	18.9108
Turbidity	5	0.2000	4.7063	0.2125	0.0425	0	2	0.4000	40.00	1.6998
		4.7063			1					44.854

Table 11. WQI for the groundwater samples in the study area

Site no	Range	WQI Class	Water Quality Status	Site no	Range	WQI Class	Water Quality Status
1	44.85	II	Good Water	27	38.2	II	Good Water
2	93.18	IV	Very Poor Water	28	87.2	IV	Very Poor Water
3	84.8	IV	Very Poor Water	29	54.9	III	Poor Water
4	63.7	IV	Very Poor Water	30	55.1	III	Poor Water
5	40.7	II	Good Water	31	50.1	III	Poor Water
6	53.4	IV	Very Poor Water	32	50.3	III	Poor Water
7	134	V	Unfit for Consumption	33	48.5	II	Good Water
8	96.5	IV	Very Poor Water	34	41	II	Good Water
9	148.4	V	Unfit for Consumption	35	55.3	III	Poor Water
10	134.1	V	Unfit for	36	36	II	Good Water

			Consumption				
11	99.5	IV	Very Poor Water	37	64.53	III	Poor Water
12	97	IV	Very Poor Water	38	73.5	III	Poor Water
13	167.2	V	Unfit for Consumption	39	90.9	IV	Very Poor Water
14	119.7	V	Unfit for Consumption	40	84.1	IV	Very Poor Water
15	93.1	IV	Very Poor Water	41	57	III	Poor Water
16	107.9	V	Unfit for Consumption	42	83.7	IV	Very Poor Water
17	88.4	IV	Very Poor Water	43	66.9	III	Poor Water
18	74.3	III	Poor Water	44	72.8	III	Poor Water
19	67.3	III	Poor Water	45	54.7	III	Poor Water
20	96.8	IV	Very Poor Water	46	61.3	III	Poor Water
21	45.3	II	Unfit for Consumption	47	38	II	Good Water
22	65.9	III	Poor Water	48	70.5	III	Poor Water
23	49.3	II	Good Water	49	68.2	III	Poor Water
24	57.1	III	Poor Water	50	66.5	III	Poor Water
25	64.2	III	Poor Water	51	72.2	III	Poor Water
26	57.8	III	Poor Water				

The WQI has been determined (Table 10) for the collected samples which were used for physiochemical parameters, and The results are shown in (Table 11). 17.64% of the samples are in good water type, 43.13% of the samples are in bad water type, 27.45% of the samples are in very bad water type and 9.8% of the samples are not for drinking. Figure 9 shows a WQI pie chart. Most samples showed that the water in the study area was poor or very substandard.This may be due to the efficient process of leaching and melting the rock (Rock water interaction).Use of more pesticides for agricultural activities, leaching of industrial waste and municipal waste, extraction of more groundwater which leads to increase the concentrations of chemicals in the aquifer.

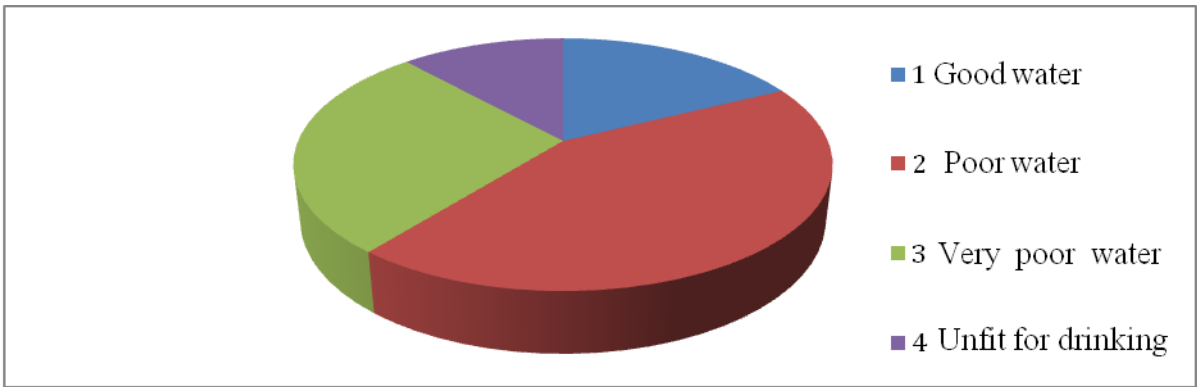

Figure 9. Pie chart indicating the result of WQI

Conclusion

The study found that the mean values of some parameters, such as F, NO3, TH, Na and K, were above the standard WHO tolerances. Hydrochemical analysis and water quality indicators are used to assess the portability of groundwater. Gibbs plot confirm that the weathering and evaporation process of rocks dominates the control of groundwater quality in the study area. Nitrate and fluoride pollution is of great concern in the study area: approximately 64% of samples have unacceptable nitrate concentrations and 21.56% of samples have unacceptable fluoride concentrations, according to WHO and BIS guidelines. The primary source of NO_3 in groundwateris because of excess usage of nitrogen fertilizers in agricultural activities and domestic sewage. By following less usage of fertilizers and following proper waste disposal techniques the concentration of NO_3can be reduced.According to the WQI, about 17.64% of samples are categorized as good water, 43.13% are categorized as inadequate water, 27.45% are categorized as very unsuitable water, and 9.8%. You can see that the sample does not meet the requirements. It is shown that the geochemistry of groundwater in the study has declined dramatically due tomany factors like water-rock interaction and anthropogenic activities. There is much scope for further studies on determining efficient methods for reducing NO_3 and F concentrations in the study area. It is suggested that water from this area needs efficient treatment in reducing high concentrations of some parameters which affect human health and also to mitigate the problems of groundwater quality deterioration, strict groundwater management plans should be established.

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