



HYDRO CHEMICAL EVALUATION OF GROUNDWATER SAMPLES IN CHINNAR RIVER BASIN, KARNATAKA, INDIA.

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Abstract: Water resources is becoming a scarce natural resources, where in a judicious and sustainable way of utilization is the need of the day. Groundwater quality studies provide an insight for various usages. By evaluating the quality aspect, conclusions can be drawn on how best the water resource can be utilized. With this context the present investigation is carried out. In the study area groundwater samples have been collected with due emphasis to spatial distribution. The samples collected were analyzed for major cations and anions, pH and electrical conductivity by standard analytical procedures. Also parameters like SAR, RSC, %Na, Kelley's ratio and Mg ratio are calculated. WQI values are computed to know the water quality in the study area. In the study area the WQI values varies between 39.6 to 201.7 with an average of 86.4. According to the WQI classification, about 6% of the total groundwater samples represent excellent water quality, 7.23.1% as good, 22.53 % as poor and about 1.40% as very poor in water quality for the study area. Thus the results are used in determination of suitability of water for various uses.

Index Terms – Groundwater, Spatial, Conductivity, Analytical

I. INTRODUCTION

The water quality is of significant concern for mankind as it is directly linked with human welfare. The groundwater is believed to be comparatively much fresh and free from pollution than surface water. The chemical composition of natural waters is affected by the soluble products due to rock weathering and decomposition in the aquifer. Thus the main factors that control the quality of water are the associated lithology, soil and to some extent land use.

The quality of groundwater particularly shallow groundwater is changing. The situation is aggravated by the problem of water pollution. The fresh water crisis is mainly due to improper management of water resources and environmental degradation, which has led to a lack of access to safe water supply. The modern civilization, industrialization, urbanization and increase in population have led to fast degradation of groundwater quality. However, the growing demand for groundwater resources has caused concerns about the sustainability of both agriculture and the economy. The available water resource has to be evaluated both for quantity and quality alike. Monitoring of groundwater quality is an effort to obtain information on chemical quality through representative sampling in different hydrogeological units. Groundwater, therefore, needs to be husbanded for its quality so it is available if and when it is really needed.

II. ACCURACY OF CHEMICAL ANALYSIS

Chemical analysis of groundwater samples plays an important role for the assessment and management of water quality. Therefore, accuracy of water analysis compositional data must be of high quality. As various instruments and other analytical techniques are involved during the chemical analysis of water samples, chances of error are possible. One has to check the results before making any decision for future use.

Accuracy of the water quality data can be tested by calculating the balance of cations and anions. An error of up to $\pm 5\%$ is tolerable, while every water sample with a calculated error outside this range should be checked. The Balance Error is given by;

$$\text{Ion Balance Error (IBE)} = \frac{(\sum \text{cations} - \sum \text{anions})}{(\sum \text{cations} + \sum \text{anions})} \times 100$$

IBE value calculated for the samples of the study area, shows that 90% of groundwater samples are below the acceptable limit and only few samples exceed the tolerable range.

III. METHODOLOGY

In the study area 73 groundwater samples were collected from various locations (Fig.1). The samples were analyzed for pH, EC, major cations and anions by adopting standard analytical procedures. The pH and EC were measured using Ph meter and Conductivity meter respectively. Calcium, magnesium, bicarbonate and chloride were estimated by titrimetric method. Sodium and Potassium were determined by flame photometer. Fluoride concentration was measured with Spectrophotometric technique. The

calculated parameters like SAR, RSC, %Na, Kelley's ratio and Mg ratio are used in determining the suitability of water for various uses.

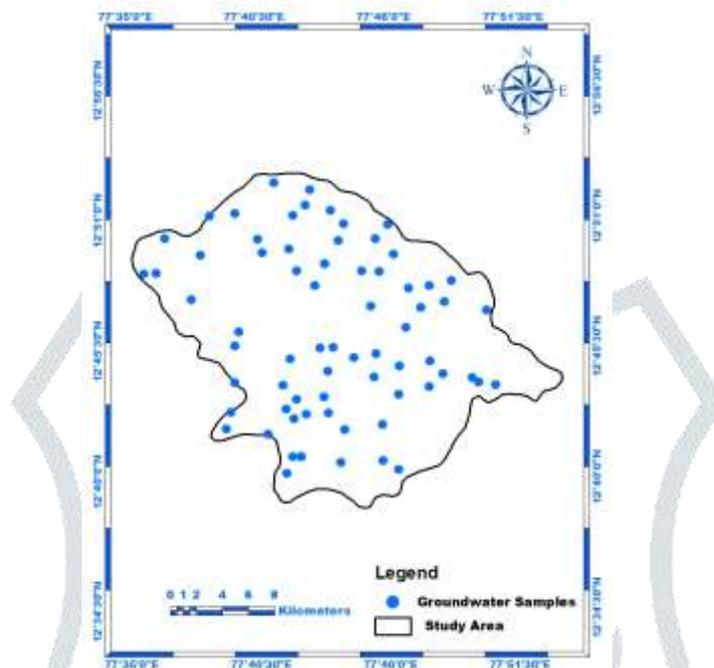


Fig. 1: Groundwater sample locations

IV. STUDY AREA

The study area covers an area of 477.42 sq. km and lies in the parts of Anekal taluk of Bangalore urban district of Karnataka (Fig.2). The Chinnar river rises at Kalkere in Bannerghatta hill ranges with an altitude of 936 m and joins Ponnair River at pedda - kulli near Hosur at an altitude of 813 m. It is an important tributary of Ponnair River. It flows towards south-eastern direction. The study area has dendritic to sub-dendritic drainage pattern. The study area lies between the longitudes of $77^{\circ} 15'$ to $77^{\circ} 48'$ E and latitudes of $12^{\circ} 40'$ and $12^{\circ} 52'$ N. The geology of the study area is largely granitic rock and gneiss. Red soil, loamy soil, alluvial soils are some of the common soil types observed in the study area. The study area is made up of plane lands, residual dome shaped hillocks and hill ranges. In general, the area forms an undulating topography with sparse vegetation, wide valley and planes. The study area is well connected with rails and roads. The nearest airport is Bangalore.

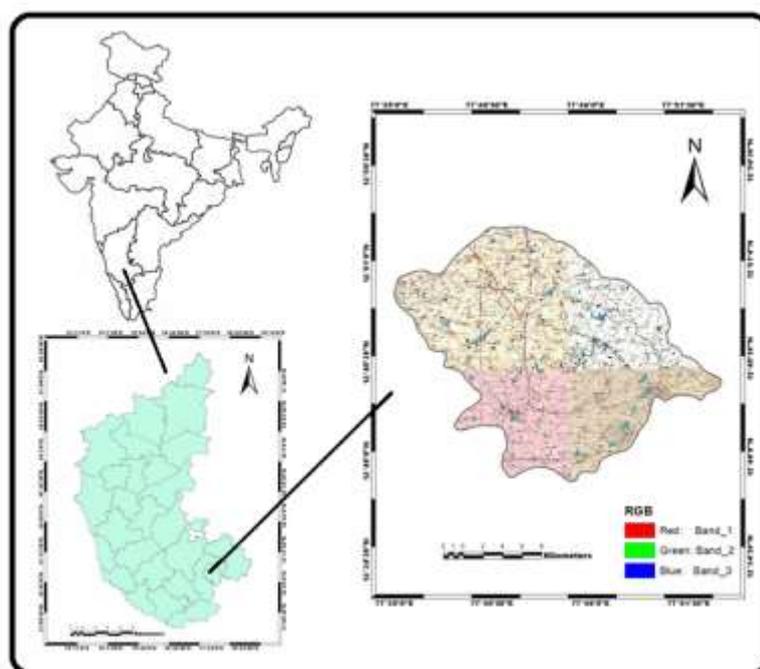


Fig.2: Study Area

V. RESULTS AND DISCUSSION

4.1 Variation of Chemical Constituents

The Calcium value in the study area ranges from 85 mg/l to 296mg/l. The average value of Calcium in the study area is 150 mg/l. The Magnesium value range in the study area ranges from 36 mg/l to 186 mg/l with an average of 88.7 mg/l. Contribution of Magnesium to the basin is mainly due to the litho units of the area. The average Sodium content for the study area is 214 mg/l, ranging from 2560 mg/l to 61290 mg/l. The application of animal waste, increased use of chemical fertilizers and weathering of clay minerals viz., pyroxenes, amphiboles etc. contribute significant amount of Sodium to groundwater. Potassium concentration

varies from traces to 56mg/l, with an average of 23 mg/l in groundwater. The main source of Potassium is due to weathering of lithology rich in minerals, usage of organic fertilizers, plant and animal waste as manure has also contributed Potassium to groundwater.

Sulphate concentration in the study area varies from 41 mg/l to 516 mg/l with an average of 130.7 mg/l. Sulphide minerals, application of sulphatic soil conditioners and excess use of organic fertilizers contributes Sulphates to groundwater. Chloride concentration in the study area ranges from 175 mg/l to 1123 mg/l, with an average of 465.5 mg/l. Improper agricultural practices and domestic sewage adds Chloride to groundwater. Nitrate concentration varies from 14.5 mg/l to 112 mg/l with an average of 51 mg/l. Nitrate is attributed due to agro inputs. Fluoride concentration in the study area varies from 0.5 mg/l to 2.2 mg/l with an average of 0.8 mg/l. It is basically due to litho units contribution.

EC and pH

The conductivity (EC) indicates the ionic concentration. The conductivity depends on temperature, concentration and type of ions present (Hem,1985). EC of the groundwater varies from 1.1 to 4.5 microsiemens/cm at 25°C with an average of 2.5. The pH of water indicates its quality and provides information on geochemical equilibrium or Solubility calculation (Hem,1985). pH values of the study area vary from 6.5 to 8.9, with an average of 7.5. The desirable limit of pH in drinking water is 7 to 8.5 and the groundwater samples of the study area are within the permissible limit with few exceptions.

4.2 Hydro chemical Facies

The geochemical facies can be known by plotting the analytical values obtained from the groundwater on Piper (1944) trilinear diagrams. These plots include two triangles, one on left hand side for plotting cations and the other on right hand side for plotting anions. The cation and anion fields are then combined to be represented as a single point in the central diamond shaped field. Then based on this inference is drawn to which hydrogeochemical facies belongs. This diagram reveals similarities and differences among groundwater samples because those with similar qualities will tend to plot together as groups (Todd, 2001). This diagram is very useful in bringing out chemical relationships among groundwater in more definite terms (Walton, 1970). The plot shows that 62.97%, 53.92%, 44.07% and 37.02% of the samples fall in the field 1, 3, 4 and 2 of the Piper trilinear diagram respectively. From the plot it is observed that majority of samples are of Ca-HCO₃ type followed by Mixed Ca-Na-HCO₃ type and a little percentage falls under Na-HCO₃ type suggesting that throughout most of the study area alkaline earths (Ca⁺ and Mg⁺) dominate over alkalis (Na⁺ and K⁺) and weak acids (HCO₃⁻) dominate over strong acids (Cl and SO₄⁻) in the groundwater.

4.3 WQI based Classification

The computed value of WQI for the study area are grouped into different classes Viz., excellent, good, poor and very poor as shown in the table above. In the study area the WQI values varies between 39.6 to 201.7 with an average of 86.4. According to the WQI classification, about 6% of the total groundwater samples represent excellent water quality, 7.23.1% as good, 22.53 % as poor and about 1.40% as very poor in water quality for the study area.

4.4 Groundwater Criteria for Irrigation

The problems of water quality have become important than the quantity, as health and environmental problems are getting more serious. Factors like geology, soil, effluents, sewage and other environmental conditions in which the water happens to stay or move and interact with ground and biological characteristics. This influences greatly on the groundwater quality of an area. The excess amount of dissolved ions such as sodium, bicarbonate and carbonate in irrigation water effects plants and soils, thus reducing the productivity.

4.4.1 Sodium Adsorption Ratio (SAR)

One of the method that evaluates the suitability of the groundwater for irrigation is SAR. The SAR values of a given water sample indicates sodium hazard of that water for soil and crops. It is calculated as below;

$$SAR = \frac{Na^+}{\sqrt{Ca^{2+}+Mg^{2+}/2}} \quad (\text{all values in meq/l.})$$

SAR values of the groundwater in the study area varies from 0.58 to 9.2 meq/l, with an average of 3.37 meq/l. Richards (1954) classified the water into four groups, based on that the samples of the study areas falls in excellent category. Hence from the classification it is evident that the water quality for agriculture is excellent. Also the correlation of SAR and conductivity indicates that out of 73 samples 46 samples fall in C2-S1 and 20 samples in C3-S1 class indicating low to medium salinity and moderate alkalinity and lower sodium content. Rest of the few samples falls under C4-S2, C2-S2 and C3-S2 class indicating high salinity to moderate sodium hazard. Thus groundwater of the study area is suitable for irrigation.

4.4.2 Residual Sodium Carbonate (RSC)

Residual sodium carbonate is calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water for agricultural purpose. Residual alkalinity represents the amount of sodium carbonate and sodium bicarbonate in the water and is said to be present in a water sample if the carbonate and bicarbonate ions exceed the concentrations of calcium and magnesium ions. RSC gives an account of calcium and magnesium in the water sample as compared to carbonate and bicarbonate ions (Eaton, 1950). Residual Sodium Carbonate (RSC) predicts the accumulation of sodium in the soil based on the potential precipitation of calcium/magnesium carbonate.

CO₃⁻ and HCO₃⁻ hazardous effect on the quality of water for agricultural purpose is best studied by calculating RSC (Eaton, 1950) and is given by;

$$RSC=(CO_3+HCO_3)-(Ca+Mg) \quad (\text{all values in meq/l.})$$

The RSC in groundwater samples of the study area varies from -11.1 to 8 meq/l. with an average of -0.77.

4.4.3 Permeability Index (PI)

High sodium in the irrigation water can cause severe problems to soil permeability. Permeability index is influenced by sodium, calcium, magnesium and bicarbonate contents in the soil. The WHO (1989) uses a criterion for assessing the suitability of water for irrigation based on permeability index. Permeability index is used for the determination of suitability for groundwater for irrigation and is obtained by considering the ions which influence permeability.

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100 \quad (\text{all values in meq/l.})$$

Doneen (1966) evolved a criterion for assessing the suitability of water for irrigation based on the permeability index. PI values of groundwater samples vary from 25.97% to 107.0% with an average of 64.61%. The Doneen chart reveals that 23.94% of samples fall in class - I, 71.83% of samples in class-II and only 4.22% in class-III. Hence, groundwater samples falling in class - I and II are generally good for irrigation.

4.4.4 Percent Sodium (% Na)

Sodium percent is an important factor for studying sodium hazard. It is also used to qualify water for agricultural purposes. Excess sodium with carbonate form alkali soils, whereas with chloride, saline soils. High percentage sodium water for irrigation purpose may stunt the plant growth and reduces soil permeability (Joshi et. al., 2009).

The Sodium percentage for a given water sample also determine its suitability for irrigation. A maximum up to 60% of sodium in groundwater is allowed for irrigation (Wilcox, 1955).

$$\% Na = \frac{(Na^+ + K^+)}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100 \quad (\text{all values in meq/l.})$$

% Na in the study area varies from 12.9 % to 85.3% with an average of 47 %. Plotting of % Na values on Wilcox diagram indicates that 18 samples fall under excellent category, 40 samples in good to permissible, 6 samples under permissible to doubtful and 6 samples in doubtful to unsuitable and 3 samples in unsuitable class. Hence, majority of groundwater samples show good to permissible class of water for irrigation.

4.4.5 Magnesium Hazard (MH)

Generally, alkaline earths are in equilibrium state in groundwater. If soils have more alkaline earths, they reduce a crop yield. Szaboles and Darab (1964), have proposed a magnesium hazard in relation to alkaline earths for irrigation. This hazard is expressed in terms of magnesium hazard (MH), which is computed by following equation;

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \quad (\text{all values in meq/l.})$$

If the water contains more than 50% of magnesium hazard, such water quality is considered to be harmful for irrigation, as the MH adversely affects the crop growth. The computed values of magnesium hazard from the groundwater for the study area varies from 7.6 % and 74.9% with an average of 42.2%. About 81.69% of total groundwater samples fall under safe category and the rest of the samples exceed the permissible range.

4.4.6 Kelly's Ratio (KR)

Suitability of water for irrigation purposes is also assessed based on Kelly's ratio (Kelly 1951). Ratio of sodium to calcium and magnesium is used as Kelly's ratios.

$$KR = \frac{Na^{2+}}{Ca^{2+} + Mg^{2+}} \quad (\text{all values in meq/l.})$$

Groundwater having Kelly's ration more than one is considered not-suitable for irrigation purposes. Kelly's ratio of groundwater samples of the study area ranges between 0.1 and 5.8 with a mean of 1. As per KR criteria, 87% of the groundwater samples are suitable for irrigation.

4.5 Principal Component Analysis (PCA)

Principal component analysis is a mathematical reduction of data without any elaborate assumptions (Anderson, 1958; Morrison, 1964; Wilks, 1963). It is used to emphasize variation and bring out strong patterns in a dataset. PCA uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. PCA is appropriate when obtained, measures on a number of observed variables, to develop a smaller number of artificial variables called principal components that will account for most of the variance in the observed variables. To understand the variation of ionic concentrations of groundwater in the study area PCA technique has been used and the results are discussed.

Initially the correlation matrix of the chemical parameters is computed. The first four Eigen values accounts for 76.20% and the rest constitutes 23.80% of the total variance. Thus the first three values are used to explain hydro chemical process. The percent of variance of components are 48.5%, 10.9%, 9.1% and 7.7% respectively. The First Component has good loading over Ca, SO₄, Cl, TH, EC and TDS and moderate loading over the rest of the parameters. Since most of the cations have good correlation with TDS, the first factor can be called as TDS factor. There is equal loading on TDS and EC which explains the direct relationship between them. Second principal component which accounts for 10.9% of the total variance is loaded over Fluoride, Iron, Sodium and Bicarbonate and poorly loaded over other parameters indicating negative correlation. The high weight age is due to weathering of litho units Viz., gneisses, granite and also excessive use of fertilizers in the agriculture.

Thus the factor can be considered as Sodium factor. The third Component has good loading over K, Mg, NO₃ and Na, and moderate to poor loading over the rest of the parameters. This factor accounts for 9.1% of total variance. The higher weightage over K is due to excessive utilization of potassium rich fertilizers in agricultural practices and weathering of potash feldspar rich rock

types. The fourth component accounts for 7.7% of the total variance. This component has good loading over F, pH, K and SO₄. Thus the PCA analysis is useful in grouping and regrouping of chemical parameters of least significance. Hence the results of the PCA enable to know the water - rock interaction, ion exchange process and influence of anthropogenic activity over the groundwater. The inter relationship between the different components can be analyzed by plotting the principal component one against the other. The plots reveal that the samples which are clustered together have same chemical character and differ from that of the samples outside the cluster.

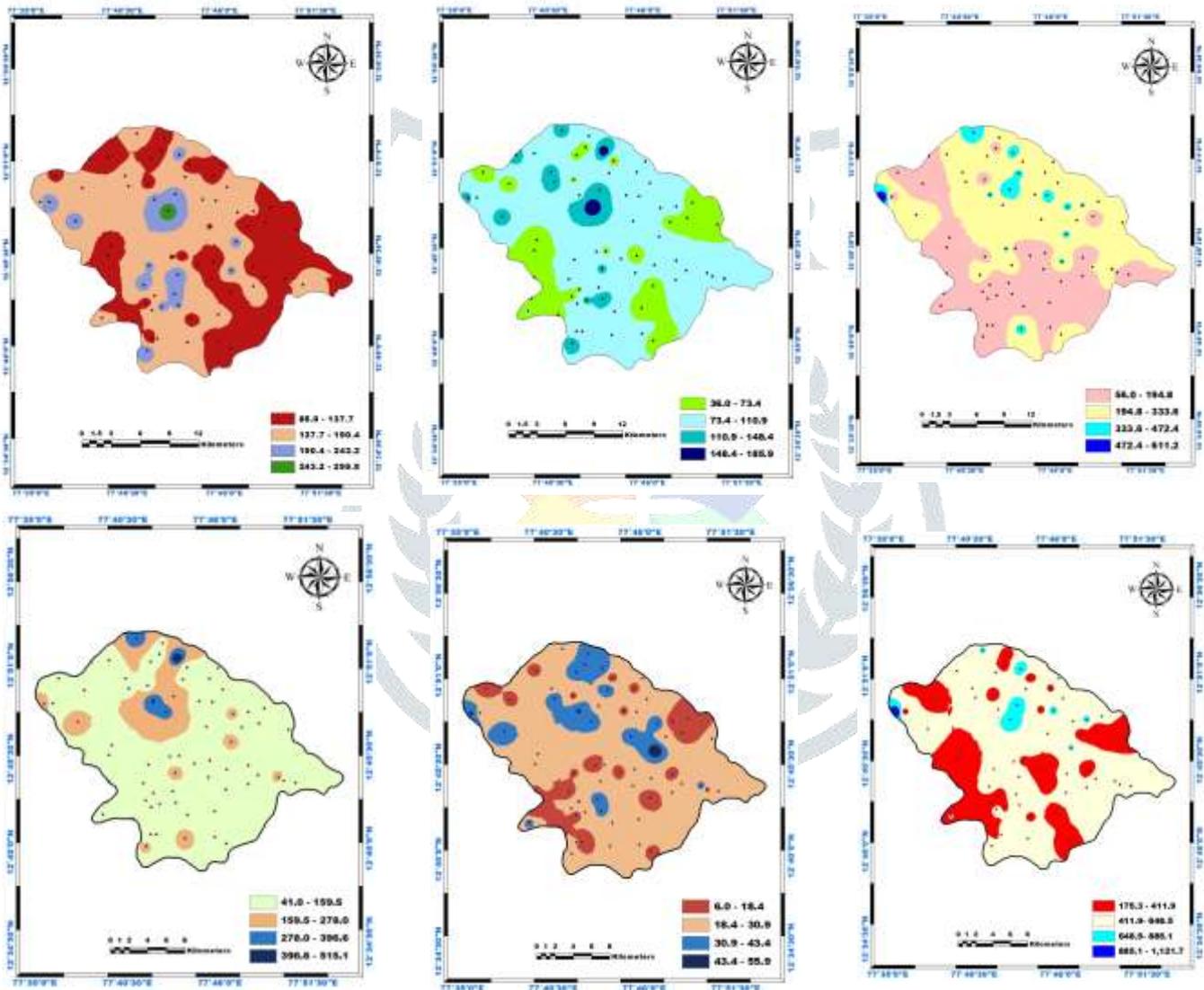


Fig.3: Iso concentration maps of Chemical parameters (Left to right: Ca, Mg, Na, K, Cl, SO₄)

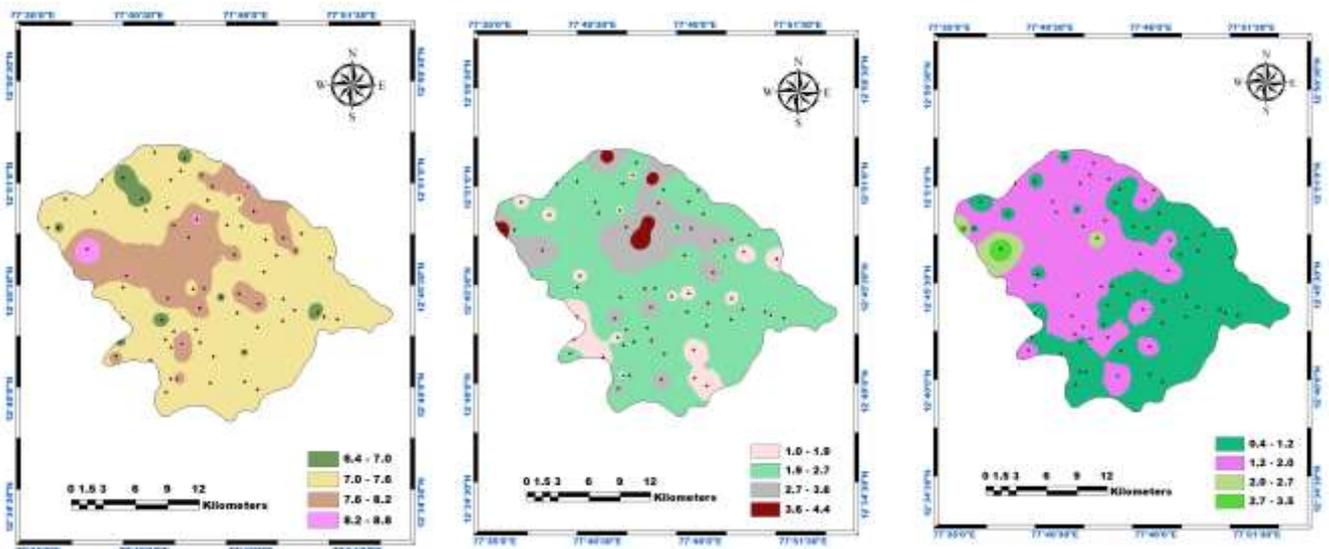


Fig.4: Iso concentration maps of Chemical parameters (Left to right: pH, EC and F)

	PH	EC	Ca	Mg	TH	Na	K	HCO ₃	SO ₄	Cl	NO ₃	F	TDS
PH	1.000												
EC	0.242	1.000											
Ca	0.284	0.722	1.000										
Mg	0.306	0.784	0.714	1.000									
TH	0.319	0.818	0.919	0.922	1.000								
Na	0.091	0.852	0.303	0.434	0.411	1.000							
K	0.067	0.582	0.417	0.469	0.468	0.443	1.000						
HCO ₃	0.320	0.715	0.670	0.525	0.654	0.479	0.422	1.000					
SO ₄	0.184	0.827	0.580	0.727	0.712	0.672	0.526	0.466	1.000				
Cl	0.144	0.918	0.604	0.744	0.729	0.842	0.507	0.433	0.712	1.000			
NO ₃	0.039	0.343	0.271	0.203	0.261	0.272	0.218	0.314	0.230	0.207	1.000		
F	0.176	0.496	0.412	0.479	0.489	0.348	0.460	0.375	0.448	0.442	0.103	1.000	
TDS	0.242	1.000	0.722	0.784	0.818	0.852	0.582	0.715	0.827	0.918	0.343	0.496	1.000

Table1: Correlation Matrix of Variables

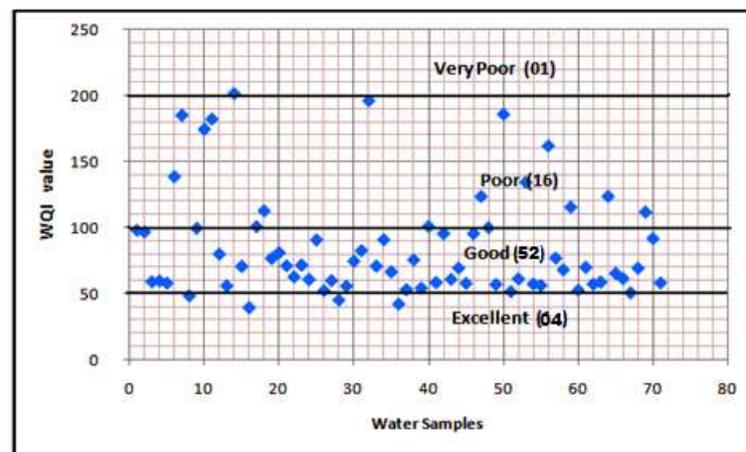


Fig.5: WQI values and water samples

VI. CONCLUSION

It is essential to ascertain the quality of water available from the various sources to whether the water is potable or not. So to know the portability conditions various parameters like Ph, EC, Chloride, Total Hardness, Total Alkalinity, Acidity and Fluoride were analyzed for the study area. WQI values are computed to know the water quality in the study area. In the study area the WQI values varies between 39.6 to 201.7 with an average of 86.4. According to the WQI classification, about 6% of the total groundwater samples represent excellent water quality, 7.23.1% as good, 22.53 % as poor and about 1.40% as very poor in water quality for the study area. According to the WQI classification, all the groundwater samples represent excellent to good water quality. Generally, the higher WQI values in the poor and very poor water quality class is due to contribution from geogenic and anthropogenic factors. Although the water quality is mainly controlled by aquifer chemistry and soils, excessive utilization of agro inputs has also compounded to the problem. Hence it can be concluded that groundwater in the study area is suitable for both drinking and domestic purpose based on evaluation of hydro chemical parameters and water quality index of groundwater.

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