Assessement of Groundwater Quality for Irrigation in Hebbal Valley, Karnataka, India

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ABSTRACT - Water resource is becoming scarce which requires judicious and sustainable way of utilization. Quality and quantity aspects of both surface and groundwater is changing. Groundwater quality studies provide an insight for various usages. By evaluating the quality aspect, conclusion can be drawn on how best the water resource can be utilized to optimum. With this background an attempt has been made to assess the quality of groundwater for irrigation in Hebbal valley. 45 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 have been calculated. Thus the results are used in determination of suitability of water for agricultural practices. The investigation points out that most of the constituents in groundwater of the study area are well within the permissible limits, except in few cases. Based on USSL classification, most of the samples are of C2-S1 class indicating low to medium salinity content. Wilcox diagram indicates that most of the samples fall under good to permissible category, indicating excellent quality for agriculture. Trilinear diagram indicates that majority of the water samples belongs to Ca, Mg - CO_3, HCO_3 and Na, K - CO_3, HCO_3 faces. Hence, the overall scenario from the present investigation is that groundwater in the study area is safe for agricultural activity.

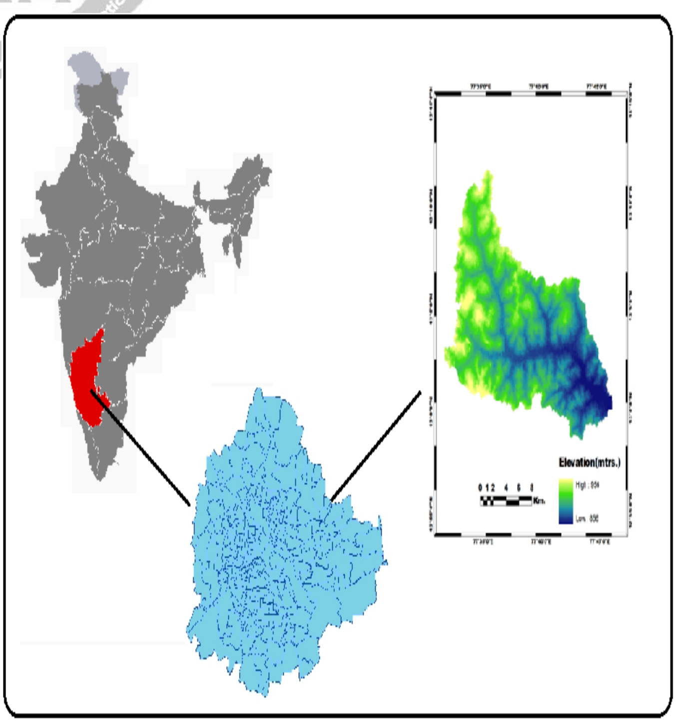
Keywords – Assessment of Ground Water, Irrigation, water resource, agricultural.

I. INTRODUCTION

Scarcity of quality groundwater has lead to the increasing interest on groundwater. It has become crucial not only for targeting of groundwater potential zones, but also monitoring and conserving this important resource (CGWB, 1985). Groundwater is an important source for domestic, agricultural and industrial use. Economic growth, increased population and other developmental activities have resulted in demand for water resource. This is also a cause for degradation of its quality. Changes in topography and drainage system directly affect both quantity and quality of the groundwater. The groundwater pollution is also due to either natural or anthropogenic activities. Groundwater quality depends on the quality of recharging precipitation, surface water and sub-surface geochemical processes. Water quality is influenced by natural and anthropogenic effects including local climate, geology and agricultural practices.

The agricultural activity to meet the food target to the ever growing population has affected the quality of land and water alike. The agro chemistry impacts *Viz.*, fertilizers and pesticides to agricultural practices has become a source of pollution of groundwater. Quality is an important consideration in any appraisal of salinity or alkalinity in an irrigated area. Water with good quality has the potential to cause maximum yield under good soil and water management practices. With this background an attempt has been made to assess the groundwater suitability for irrigation in the study area.

II. STUDY AREA



Map 1 - Study area

 DOI : 10.18231/2454-9150.2017.0017

The study area is located between 12º 50’ to 13º 5’N Latitudes and 77º 30’ to 77º 40’E Longitudes forming a part of Cauvery river basin (Map-1). The study area covers an area of 310.24 km^2 and drains into river Pinakini in Bangalore district of Karnataka. Physiographically the area is characterized by undulating topography with plains and shallow valleys. Geologically the area is covered by peninusular gneissic complex and soils includes red sandy, gravely,loamy and clay soils. The study area is located at the north eastern parts of Bangalore. The district falls in Cauvery river basin. The study area attains maximum elevation of 940 mtrs. and a minimum of 880 mtrs. above mean sea level. The study area is well connected by highways and main roads. The average annual rainfall in the study area is 820 mm.

III. METHODOLOGY

In the study area 45 groundwater samples have been collected from various locations. The sampling points were located in areas where there was no treated water supply. The samples so collected were analysed for various physico-chemical parameters by adopting standard analytical procedures. The samples were analysed for pH, electrical conductivity (EC), major cations and anions. The pH was measured with pH meter and EC with Conductivity meter. Calcium, Magnesium, Bicarbonate and Chlorides were estimated by titrimetric method. Sodium and Potassium were determined by flame photometer. Also parameters like SAR, RSC, %Na, Kelley's ratio and Mg ratio have been calculated. Geographical information system has been used to generate iso-concentration maps to depict the anomalies in the study area.

IV. RESULTS AND DISCUSSIONS

Variation of Chemical Constituents

The Calcium value in the study area varies from 28.4 mg/l to 177.6 mg/l with an average of 77.8 mg/l. Few samples are found to exceed the permissible limit. Weathering of gneissic and granitic rock contributes Calcium to the groundwater. The Magnesium value in the study area ranges from 15.54 mg/l to 68.5 mg/l with an average of 34.5 mg/l. Contribution of Magnesium in the study area is mainly due to the lithounits of the area. Weathering of schists and gneisses enrich the Magnesium content in groundwater.

The average Sodium content for the study area is 80.11 and 65.9 mg/l. Potassium concentration varies from 2.32 to 71.8 mg/l with an average of 16.91 mg/l. Chloride concentration in the study area range from 51 mg/l to 167 mg/l with an average of 89.05 mg/l. Sulphate concentration in the study area varies from 19 mg/l to 203 mg/l with an average of 51.80 mg/l. Nitrate concentration in the study area varies from 13 mg/l to 46 mg/l with an average of 26 mg/l. The prescribed limit for Nitrate in the drinking water is 45 mg/l (WHO). Few groundwater samples of the study area are above the permissible limit.

WATER QUALITY CRITERIA FOR AGRICULTURE

The suitability of groundwater for irrigation is dependent on factors like soil texture, composition, crop growth and irrigation practices in addition to chemical characteristics of water. The quality of water for agriculture is very much influenced by the constituents of the soil which is to be irrigated and the water being utilized.

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. The excess amount of dissolved ions such as sodium, bicarbonate and carbonate in irrigation water effects plants and soils, thus reducing the productivity. Excess salinity reduces the osmotic activity of plants, which interferes with the absorption of water and nutrients from the soil (Thorne and Peterson, 1954). The salts besides affecting growth of plant directly, also affects soil structure, affecting soil permeability, aeration, texture and makes soil hard (Trivedy and Geol, 1984) along with salinity, indices such as sodium adsorption ratio (SAR), sodium percentage (Na %), residual sodium carbonate (RSC), and permeability index (PI), Magnesium hazard (MH), are important parameters for determining the suitability of ground water for irrigation uses which have been discussed as below.

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

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

SAR values of the groundwater in the study area varies from 0.75 to 2.43 meq/l, with an average of 1.62 meq/l. Richards (1954) classified the water into four groups, based on that the samples of the study areas falls in excellent category.

SAR	Water Class	No. of Samples
< 10	Excellent	45
10-18	Good	0
18-26	Fair	0
>26	Poor	0

Hence from the classification it is evident that the water quality for agriculture is excellent. Also the correlation of SAR and conductivity (Fig.1) indicates that out of 45 samples 38 samples falls in C_2-S_1 class indicating low to medium salinity and moderate alkalinity and lower sodium content. Rest of the few samples falls in C_2-S_2 and C_3-S_2 class indicating high salinity to moderate sodium hazard. Thus groundwater of the study area is suitable for irrigation.

 DOI : 10.18231/2454-9150.2017.0017

ISSN : 2454-9150 Vol-03, Issue-07, Oct 2017

Class	Quality of Water	No. of Samples
C_2-S_1	**Medium salinity - Low sodium hazard**	**38 (84.44%)**
C_3-S_1	**High salinity - Low sodium hazard**	**0 (0%)**
C_3-S_3	**Very high salinity - Low sodium hazard**	**0 (0%)**
C_2-S_2	**Medium salinity - Medium sodium hazard**	**3(6.66%)**
C_3-S_2	**High salinity - Medium sodium hazard**	**4 (8.89%)**
C_4-S_2	**Very high salinity - medium sodium hazard**	**0 (0%)**
C_4-S_3	**Very high salinity - high sodium hazard**	**0 (0%)**
	Total	**45 (100%)**

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. CO_3^{2-} and HCO_3^- 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 -8.21 to 0.74 meq/l. with an average of -2.32.

RSC	Water Class	No. of Samples
< 1.25	Safe	45 (100%)
1.25-2.5	Permissible	0 (0%)
>2.5	Unsuitable	0 (0%)

(USEPA, 1999)

All the groundwater samples are within the safe to permissible category for irrigation. Thus indicating that groundwater is suitable for irrigation purpose in the study area.

Water Class	No. of Samples
Excellent	20
Good to permissible	25
Permissible to Doubtful	0
Doubtful to Unsuitable	0
Unsuitable	0

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.

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

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 28.33% to 76.1% with an average of 54.1%. The Doneen chart (Fig. 3) reveals that 21.94% of samples fall in class - I, 73.83% 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.

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).

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

% Na in the study area varies from 21.39 % to 61.14% with an average of 44.43 %. Plotting of % Na values on Wilcox diagram (Fig. 2) indicates that 20 samples fall under excellent category, 25 samples in good to permissible class. Hence, majority of groundwater samples show good to permissible class of water for irrigation.

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;

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

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 21.9 % and 58.9 % with an average of 42.8%. About 80.69% of total groundwater samples fall under safe category and the rest of the samples exceed the permissible range.

 DOI : 10.18231/2454-9150.2017.0017

ISSN : 2454-9150 Vol-03, Issue-07, Oct 2017

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.

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

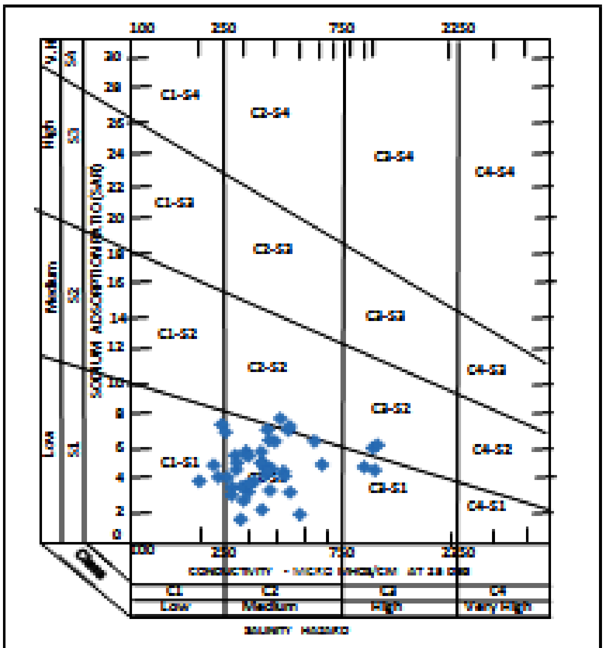
Groundwater having Kelly's ration more than one is considered not suitable for irrigation purposes. Kelly's ratio of groundwater samples of the study area ranges between 0.16 and 0.84 with a mean of 0.47. As per KR criteria, all the groundwater samples in the study area generally suitable for irrigation.

Chlorides and Sulphates in Agricultural Water

Chloride and Sulphate when excess in water, affect the agricultural practices. Eaton (1942) has given the permissible range for both Cl and SO_4 for irrigation purpose and is as below for the study area.

Range (meq/ltr.)	Water Class	No. of samples Cl	No. of samples SO_4
< 4	Excellent	44	44
4.1-7	Good	1	1
7.1-12	Permissible	0	0
12.1-20	Doubtful	0	0
> 20.1	Unsuitable	0	0

Thus it is seen that majority of the samples fall in Excellent to Good category of water class.



USSL diagram for classification of Irrigation Waters

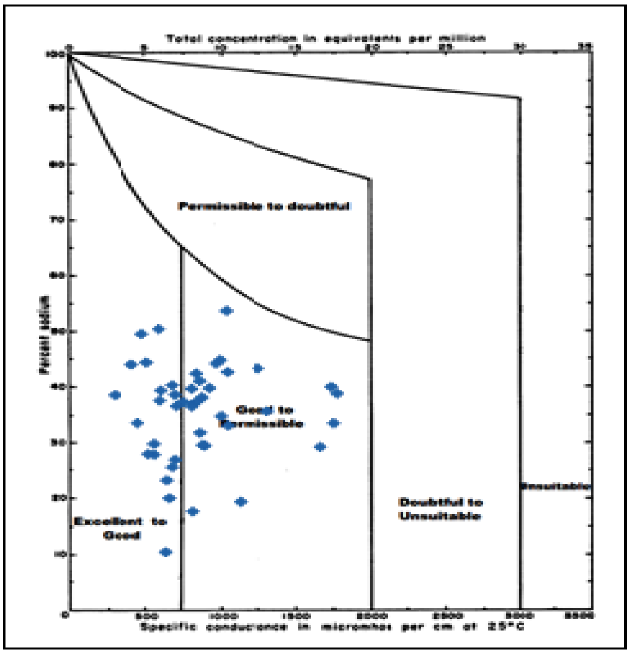


Fig. 2: Wilcox diagram

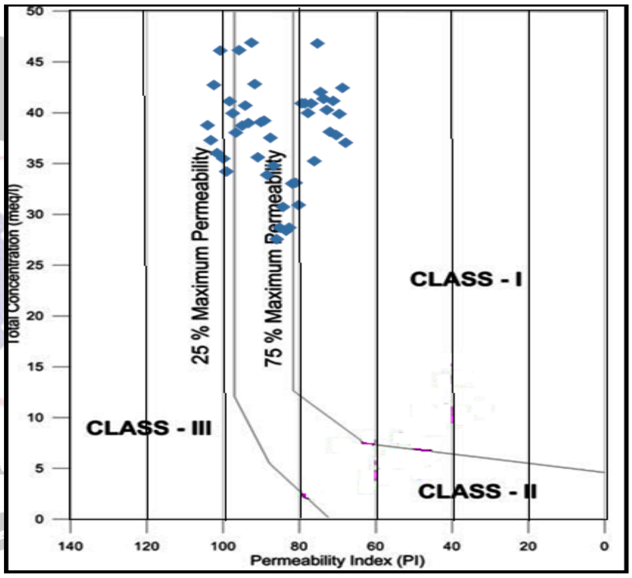


Fig.3: Permeability Index diagram

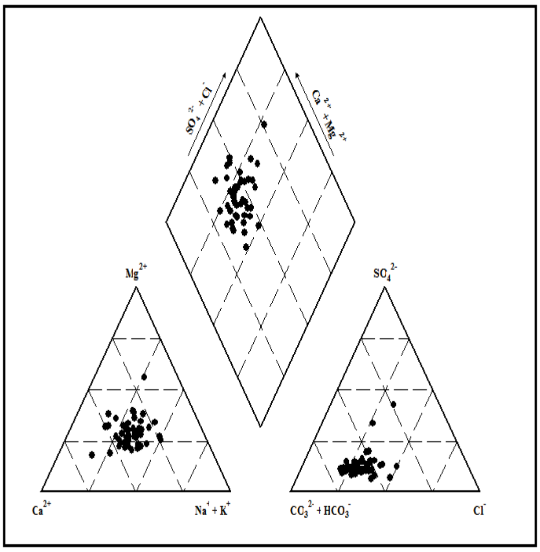
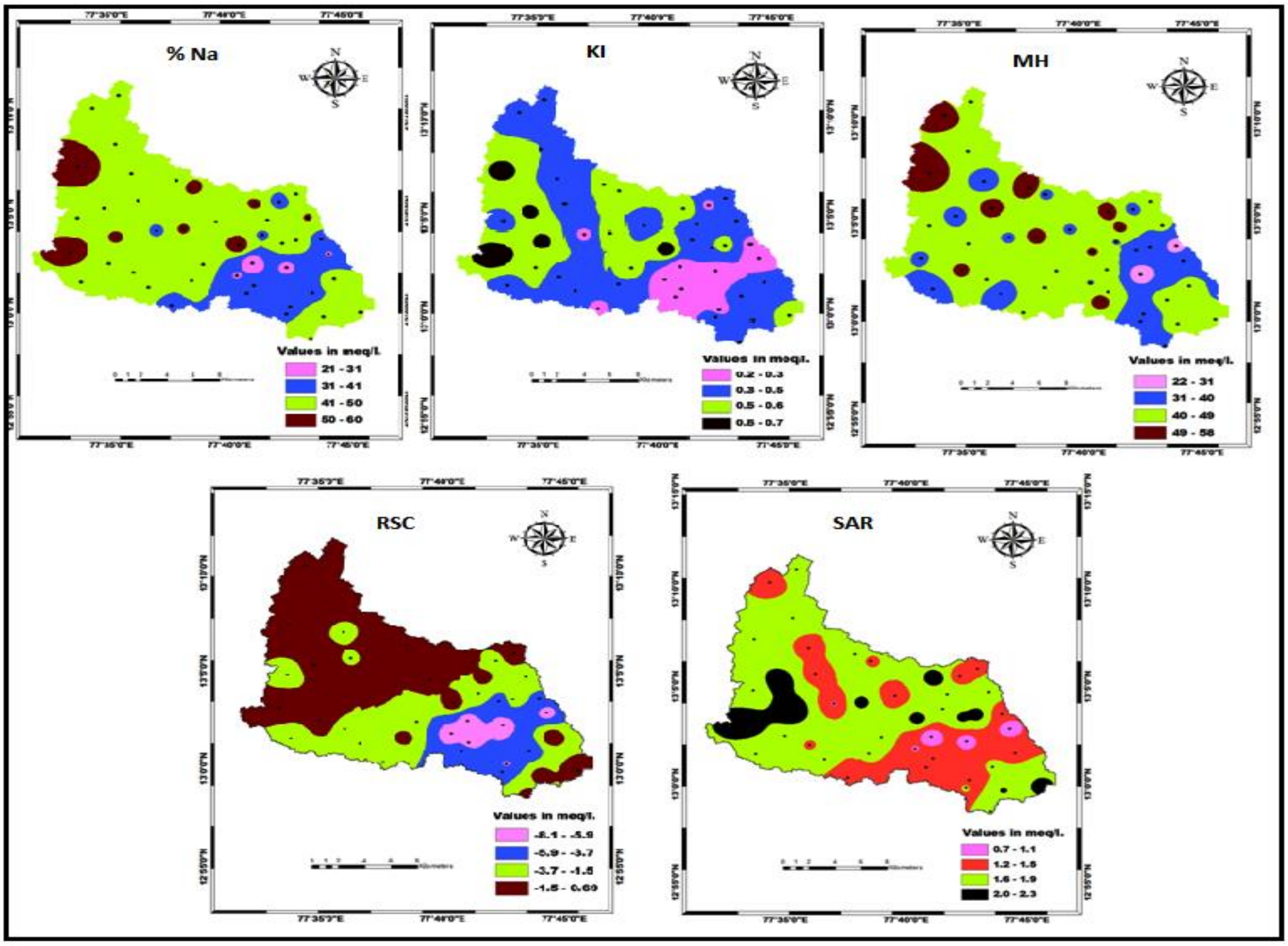


Fig.4: Piper Trilinear diagram

DOI : 10.18231/2454-9150.2017.0017

ISSN : 2454-9150 Vol-03, Issue-07, Oct 2017



Map – 2: Iso-concentrations of irrigation chemical parameters.

V. CONCLUSIONS

The analysed and calculated chemical parameters of groundwater in the study area reveals that according to USSL classification, most of the samples belongs to C2-S1 class indicating low to medium salinity content. Wilcox diagram indicates that most of the samples fall under good to permissible indicating excellent quality for irrigation use. Trilinear diagram indicates that majority of the water samples belongs to Ca,Mg-CO_3,HCO_3 and Na,KCO_3,HCO_3 facies. Kelly's ratio of groundwater in the study area also points out the suitability of groundwater for irrigation. Even the Magnesium ratio values indicate that the groundwater is suitable for agricultural activities except in few cases. The RSC values of all the samples are well within the safe quality category for irrigation indicating that water is suitable for irrigation purpose. Hence, in general it can be concluded that the quality of groundwater in the study area is safe and suitable for irrigation with few exceptions.

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