

## Hydrochemical Analysis and Evaluation of Groundwater Quality in Tumkur Taluk, Karnataka State, India

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**Abstract:** Tumkur Taluk is located in the southeastern corner of Karnataka state between 13° 06'30" to 13° 31' 00" North latitude and 76° 59' 00" to 77° 19' 00" East Longitude. The Taluk spreads over an area of 1043 sq.km falling within the semiarid region and frequently facing water scarcity as well as quality problems. The major sources of employment are agriculture, horticulture and animal husbandry, engaging almost 80% of the workforce. Water samples are collected from 269 stations during pre-monsoon and 279 locations during post-monsoon of the year 2006, and were subjected to analysis for chemical characteristics. The type of water that predominates in the study area is Ca-Mg-HCO<sub>3</sub> type during both pre- and post-monsoon seasons of the year 2006, based on hydro-chemical facies. Besides, suitability of water for irrigation is evaluated based on sodium adsorption ratio, residual sodium carbonate, sodium percent, salinity hazard and USSL diagram.

**Keywords:** Groundwater, chemical characters, chemical classification, SAR, RSC, USSL diagram.

### Introduction

Water quality analysis is one of the most important aspects in groundwater studies. The hydro chemical study reveals quality of water that is suitable for drinking, agriculture and industrial purposes. Further, it is possible to understand the change in [1, 2] quality due to rock-water interaction or any type of anthropogenic influence. Groundwater often consists of seven major chemical elements- Ca<sup>+2</sup>, Mg<sup>+2</sup>, Cl<sup>-1</sup>, HCO<sub>3</sub><sup>-1</sup>, Na<sup>+1</sup>, K<sup>+1</sup>, and SO<sub>4</sub><sup>-2</sup>. The chemical parameters of groundwater play a significant role in classifying and assessing water quality. Considering the individual and paired ionic concentration, certain indices are proposed to find out the alkali hazards. Residual sodium carbonate (RSC) can be used as a criterion for finding the suitability of irrigation waters. It was observed that the criteria used in the classification of waters for a particular purpose considering the individual concentration may not find its suitability for other purposes and better results can be obtained only by considering the combined chemistry of all the ions rather than individual or paired ionic characters [3-5]. Chemical classification also throws light on the concentration of

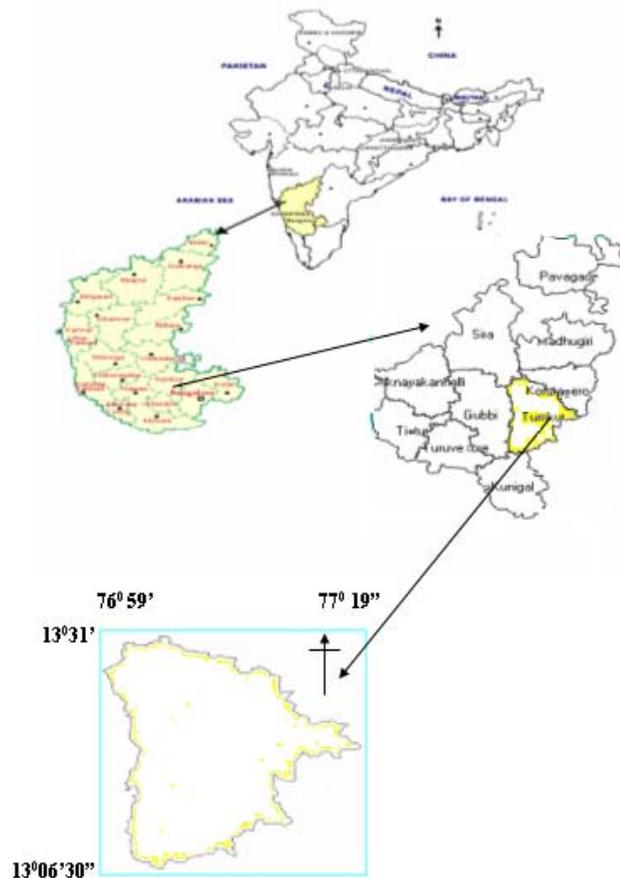
various predominant cations, anions and their interrelationships. A number of techniques and methods have been developed to interpret the chemical data. Zaporozee [6] has summarized the various modes of data representation and has discussed their possible uses.

Presentation of chemical analysis in graphical form makes understanding of complex groundwater system simpler and quicker. Methods of representing the chemistry of water like Collin's bar diagram [5], radiating vectors of Maucha [7], and parallel and horizontal axes of Stiff [8], have been used in many parts of the world to show the proportion of ionic concentration in individual samples. Subramanian [9] followed a series of methods to interpret and classify the chemistry of groundwater in hard rock, including coastal zones in the southern parts of India.

The objective of the present work is to discuss the major ion chemistry of groundwater of Tumkur Taluk. In this case the methods proposed by piper, Back and Hanshaw, Wilcox, Eaton, Todd [10] and USSL (US Salinity Laboratory) classification have been used to study critically the hydrochemical characteristics of groundwater of Tumkur Taluk.

**Study Area**

Tumkur Taluk is located in the southeastern corner of Karnataka state between 13° 06'30" to 13° 31' 00" North latitude and 76° 59' 00" to 77° 19' 00" East longitude (Fig. 1) and covers an area of 1043 sq.km with a population of 5, 16,661 [11]. The major sources of employment are agriculture, horticulture and animal husbandry, which engage almost 80% of the workforce. The major industries are that of chemicals, oil, cotton, soap, tools, food processing, rice mills, stone crushing and mining. Occurrence, movement and storage of groundwater are influenced by lithology, thickness and structure of rock formations. Weathered and fractured granites, granitic gneiss form the main aquifer in Tumkur, Taluk. Ground water in the study area occurs under water table conditions in the weathered and fractured granite, Gneisses. There is no perennial river in the study area. The major ion chemistry of groundwater of Tumkur, Taluk has not been studied earlier.

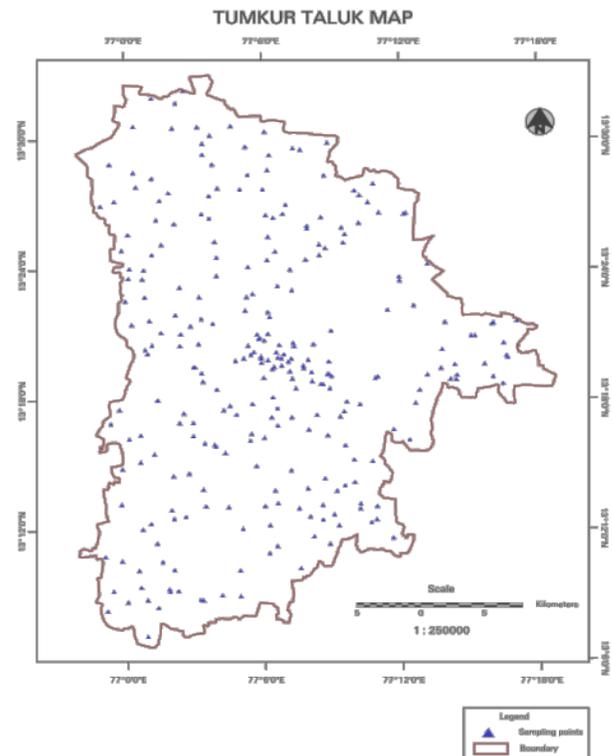


**Figure 1: Location map**

**Methodology**

Groundwater samples were collected from 237 locations from rural Tumkur and 32 samples from Tumkur

city limits during pre-monsoon period (February 2006). Post-monsoon (December 2006) period samples were collected from 237 locations from rural Tumkur Taluk and 42 locations from Tumkur city limits (Fig. 2). The collected water samples were transferred into pre-cleaned polythene container for analysis of chemical characters. Chemical analyses were carried out for the major ion concentrations of the water samples collected from different locations using the standard procedures recommended by APHA-1994 [12]. The analytical data can be used for the classification of water for utilitarian purposes and for ascertaining various factors on which the chemical characteristics of water depend.



**Figure 2: Groundwater sampling locations**

**Results and Discussion**

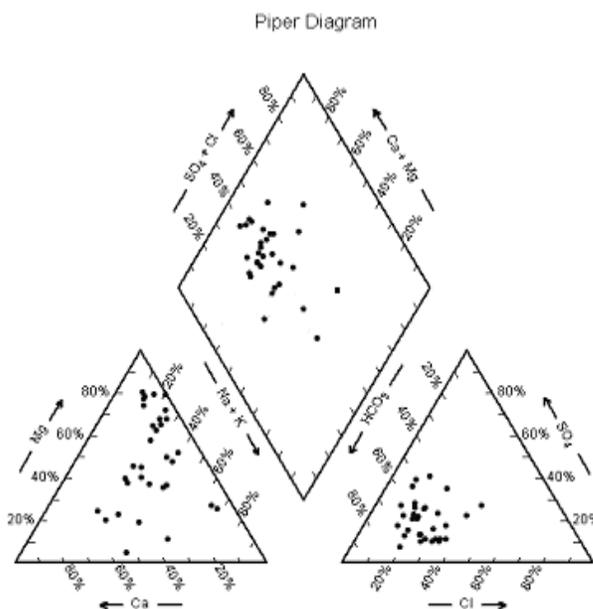
Maximum and minimum concentration of major ions present in the groundwater from the study area is presented in Table 1. The Piper-Hill diagram [13] is used to infer hydro-geochemical facies. These plots include two triangles, one for plotting cations and the other for plotting anions. The cations and anion fields are combined to show a single point in a diamond-shaped field, from which inference is drawn on the basis of hydro-geochemical facies concept. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods.

Chemical data of representative samples from the study area presented by plotting them on a Piper-tri-linear diagram for pre-and post-monsoon (figures 3 and 4).

These diagrams reveal the analogies, dissimilarities and different types of waters in the study area, which are identified and listed in Table 2. The concept of hydrochemical facies was developed in order to understand and identify the water composition in different classes.

**Table 1:** Maximum and minimum concentration of major ions in groundwater samples

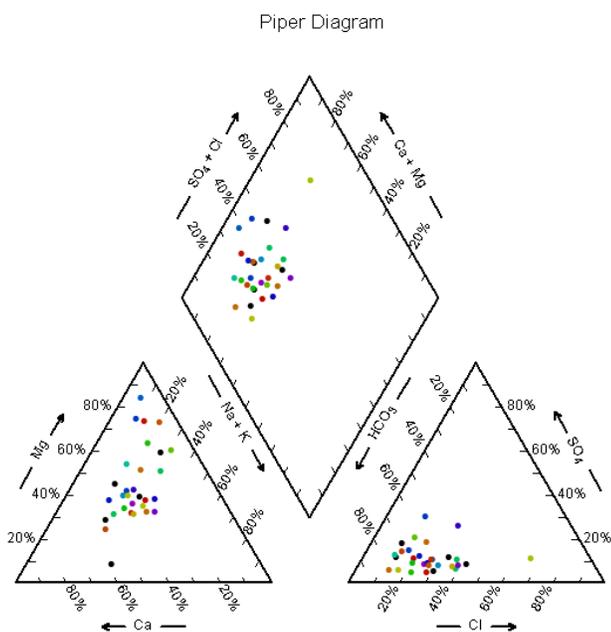
Ions	Pre-monsoon samples (mg l <sup>-1</sup> )		Post-monsoon samples (mg l <sup>-1</sup> )	
	Min	Max	Min	Max
Na <sup>+1</sup>	4	140	9	109
K <sup>+1</sup>	0	27	0	36
Ca <sup>+2</sup>	1.6	174.7	8	174
Mg <sup>+2</sup>	0.24	229.4	5.6	169
CO <sub>3</sub> <sup>-2</sup>	10	40	10	30
HCO <sub>3</sub> <sup>-1</sup>	45	550	65	602
Cl <sup>-1</sup>	4.5	662	12	340
SO <sub>4</sub> <sup>-2</sup>	0	173.5	1.2	142
Total hardness	70	1060	55	824



**Figure 4:** Pre-monsoon groundwater samples plotted in piper-Trilinear diagram

**Table 2:** Characterization of groundwater of Tumkur taluk of Karnataka on the basis of Piper tri-linear diagram

Subdivision of the diamond	Characteristics of corresponding subdivisions of diamond-shaped fields	Percentage of samples in this category	
		Pre-Monsoon	Post-Monsoon
1	Alkaline earth (Ca+Mg) Exceed alkalies (Na+K)	90	100
2	Alaklies exceeds alkaline earths	10	0
3	Weak acids (CO <sub>3</sub> +HCO <sub>3</sub> ) exceed Strong acids (SO <sub>4</sub> +Cl)	87.5	91
4	Strong acids exceeds weak acids	12.5	9
5	Magnesium bicarbonate type	81	91
6	Calcium-chloride type	0	3
7	Sodium-chloride type	3	0
8	Sodium-Bicarbonate type	0	0
9	Mixed type (No cation-anion exceed 50%)	16	6



**Figure 3:** Post-monsoon groundwater samples plotted in piper-Trilinear diagram.

Facies are recognizable parts of different characters belonging to any genetically related system. Hydrochemical facies are distinct zones that possess action and anion concentration categories. To define composition class, Back and co-workers [14] suggested subdivisions of the tri-linear diagram (figure 5). The interpretation of distinct facies from the 0 to 10% and 90 to 100% domains on the diamond-shaped cation to anion graph is more helpful than using equal 25% increments. It clearly explains the variations or domination of cation and anion concentrations during pre-monsoon and post-monsoon. Ca-Mg-type of water predominated during pre-monsoon. The percentage of samples falling under Ca-Mg-type was 90 during pre-monsoon season. Similar type of water is predominated during post-monsoon also with 100 % water samples. For anion concentration, HCO<sub>3</sub>-type of water predominated during pre-monsoon with 87.5% samples and during post-monsoon with 91% samples. There is no significant change in the hydro-chemical facies noticed during the study period (pre- and post-monsoon), which indicates that most of the major ions are natural in origin. The reason is groundwater passing through igneous rocks dissolves only small quantities of mineral matters because of the relative insolubility of the rock composition.

Water hardness is caused primarily by the presence of cations such as calcium and magnesium and anions such as carbonate, bicarbonate, chloride and sulfate in water. Water hardness has no known adverse effects; however, some evidence indicates its role in heart disease [15]. Hard water is unsuitable for domestic use. In Tumkur region, the total hardness varies between 70 to 1060 ppm for the pre-monsoon (Jan-Feb 2006) period. For the post-monsoon period (Nov-Dec 2006), the value varies from 55 to 824 ppm. According to Sawyer and McCarty's [16] classification for hardness, 26 samples fall under moderately hard class and 242 samples fall under hard and very hard class for pre-monsoon water samples. The hardness classification is given in Table 3. The suitability of groundwater for irrigation purposes depends upon its mineral constituents. The general criteria for judging the quality are: (i) Total salt concentration as measured by electrical conductivity (EC) (ii) Relative proportion of sodium to other principal cations as expressed by SAR, (iii) Bicarbonate (HCO<sub>3</sub><sup>-</sup>) and (iv) Boron.

**Table 3:** Classification of water based on hardness by Sawyer and McCarthy

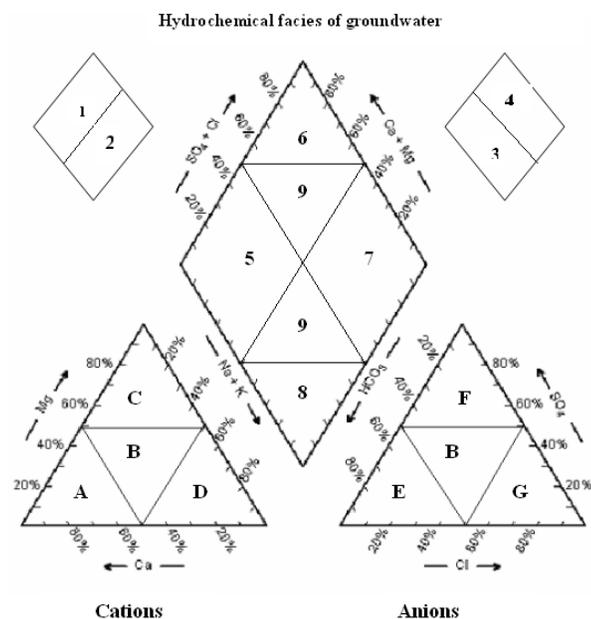
Hardness as CaCO <sub>3</sub> (ppm)	Water class	Pre-monsoon samples	Post monsoon samples
0-75	Soft	70 (1 sample)	55-70 (3 samples)
75-150	Moderate	104 - 150 (26 samples)	95-150 (26 samples)
150-300	Hard	155 - 300 (160 samples)	152-300 (196 samples)
>300	Very hard	304-1060 (82 samples)	305-824 (54 samples)

Wilcox [17] classified groundwater for irrigation purposes based on per cent sodium and Electrical conductivity. Eaton [18] recommended the concentration of residual sodium carbonate to determine the suitability of water for irrigation purposes. The US Salinity Laboratory of the Department of Agriculture adopted certain techniques based on which the suitability of water for agriculture is explained.

The sodium in irrigation waters is usually denoted as per cent sodium and can be determined using the following formula [17].

$$\% \text{ Na} = (\text{Na}^+) \times 100 / (\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+)$$

where the quantities of Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup> are expressed in milliequivalents per litre (epm).



**Legend**

- A- Calcium type
- B- No Dominant type
- C- Magnesium type
- D- Sodium and potassium type
- E- Bicarbonate type
- F- Sulphate type
- G- Chloride type

**Figure 5:** Classification diagram for anion and cation facies in the form of major-ion percentages. Water types are designed according to the domain in which they occur on the diagram segments.

The classification of groundwater samples with respect to per cent sodium is shown in Table 4. It is observed that about 250 samples are excellent to good during pre-monsoon and 254 samples are excellent to good during post-monsoon. In waters having high concentration of bicarbonate, there is tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate. RSC is calculated using the following equation.

$$\text{RSC} = (\text{HCO}_3^- + \text{CO}_3^{2-}) - (\text{Ca}^{2+} + \text{Mg}^{2+})$$

where all ionic concentrations are expressed in epm.

**Table 4:** Sodium percent water class

Sodium (%)	Water class	Pre-monsoon Samples	Post-monsoon samples
<20	Excellent	3.34-19.80 (90 samples)	7.38-19.94 (105 samples)
20-40	Good	20.04-39.92 (160 samples)	20.25-39.88 (149 samples)
40-60	Permissible	40.07-57.25 (17 samples)	40.48-59.90 (24 samples)
60-80	Doubtful	61.29-61.46 (2 samples)	63.16 (1 sample)
>80	Unsuitable	-	-

According to the US Department of Agriculture, water having more than 2.5 epm of RSC is not suitable for irrigation purposes. Groundwater of the study area is classified on the basis of RSC and the results are presented in Table 5 for both pre- and post-monsoon seasons. Based on RSC values, over 267 samples have values less than 1.25 and are safe for irrigation during pre-monsoon. During post-monsoon 272 samples were safe for irrigation. Only 2 samples in the pre-monsoon and 7 samples in the post-monsoon are fair.

**Table 5:** Groundwater quality based on RSC (Residual sodium carbonate)

RSC (epm)	Remark on quality	Pre-monsoon samples	Post-monsoon samples
<1.25	Good	16.47 - 1.24 (267 samples)	7.03 to 1.20 (272 samples)
1.25-2.5	Doubtful	1.46-1.55 (2 samples)	1.27 to 1.60 (7 samples)
>2.5	Unsuitable		

The most important characteristics of irrigation water in determining its quality are: (i) Total concentration of soluble salts; (ii) Relative proportion of sodium to other principal cations; (iii) Concentration of boron or other element that may be toxic, and (iv) Under some condition, bicarbonate concentration as related to the concentration of calcium plus magnesium. These have been termed as the salinity hazard [17], sodium hazard, boron hazard and bicarbonate hazard. In the past, the sodium hazard has been expressed as per cent sodium of total cations. A better measure of the sodium hazard for irrigation is the SAR which is used to express reactions with the soil. SAR is computed as

$$\text{SAR} = \frac{\text{Na}^+}{\left\{ \frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2} \right\}^{1/2}}$$

where all ionic concentrations are expressed in epm

The classification of groundwater samples from the study area with respect to SAR is represented in Table 6. During Pre- and post-monsoon, the SAR value of all the samples are found to be less than 10, and are classified as excellent for irrigation. When the SAR and specific conductance of water are known, the classification of water for irrigation can be determined by graphically plotting these values on the US salinity (USSL) diagram (figure 6 & 7). The groundwater of Tumkur taluk is in general Ca-Mg-HCO<sub>3</sub> type during both pre- and post monsoon seasons of the year 2006. About 98% of the samples are grouped within C2S1 and C3S1 classes in both pre- and post-monsoon (figure 6 & 7).

**Table 6:** Sodium hazard classes based on USSL classification

Sodium Hazard class	SAR in Equivalents per mole	Remark on quality	Pre-monsoon samples	Post-monsoon samples
(Alkalinity)				
S1	10	Excellent	0.11-3.54	0.30-3.52 (all 269 samples)
S2	10 - 18	Good		(all 279 samples)
S3	18-26	Doubtful		
S4 and S5	>26	Unsuitable		

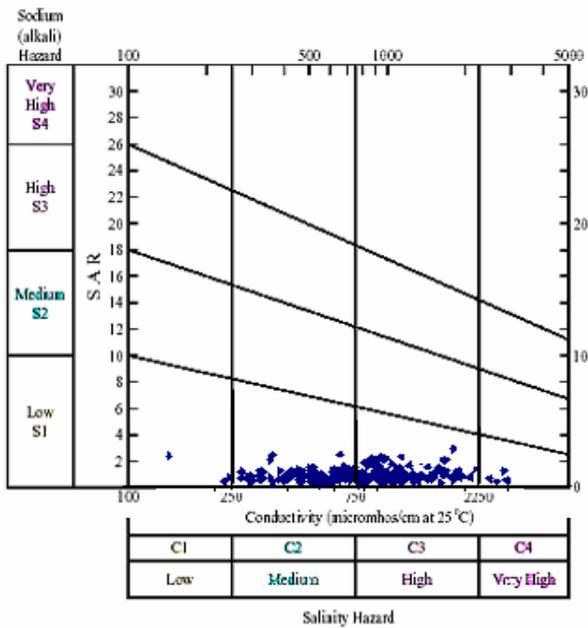


Figure 6: USSL classification of groundwater during pre-monsoon

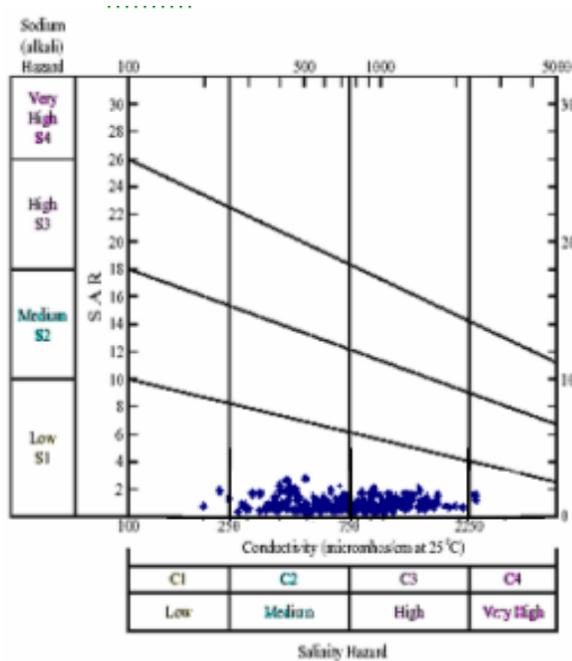


Figure 7: USSL classification of groundwater during post-monsoon

For the purpose of diagnosis and classification, the total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of specific conductance. Classification of groundwater based on salinity hazard is presented in table 7. It is found from the EC value, only 4 samples during pre-monsoon and 3 samples during post-monsoon were found to be unsuitable for irrigation purposes.

Table 7: Salinity hazard classes

Salinity hazard class	EC in (micro-mohs/cm)	Remark on quality	Pre-monsoon samples	Post-monsoon samples
C1	100-250	Excellent	130-230 (3 samples)	200-230 (2 samples)
C2	250-750	Good	260-750 (129 samples)	270 – 750 (147 samples)
C3	750-2,250	Doubtful	760-2200 (133 samples)	760 – 2050 (127 samples)
C4 & C5	>2,250	Unsuitable	2500-3000 (4 samples)	2270-2300 (3 samples)

In Tumkur, Taluk, the groundwater is generally Ca-Mg-HCO<sub>3</sub> type, which is mainly due to the geology of the area which comprises igneous rocks of crystalline nature, in which the major units are gneisses and granites. Ground water in the study area occurs under water table conditions in the weathered and fractured granite, Gneisses.

Conclusions

1. The type of water that predominates in the study area is Ca-Mg-HCO<sub>3</sub> type during both pre-and post-monsoon seasons of the year 2006, based on hydro-chemical facies.
2. Though the suitability of water for irrigation is determined based on SAR, %Na, RSC and Salinity hazard, it is only an empirical conclusion. In addition to water quality, other factors like soil type, crop type, crop pattern, frequency and recharge (rainfall), climate, etc. have an important role to play in determining the suitability of water.
3. Water that is not suitable based on the above classification may be suitable in well-drained soils.
4. The suitability of water for irrigation is evaluated based on SAR, %Na, RSC and salinity hazards. Most of the samples in Tumkur, Taluk fall in the suitable range for irrigation purpose either from SAR, % Na or RSC values.
5. About 98% of the samples are grouped within C2S1 and C3S1 classes in both pre- and post-monsoon season (figure 6 & 7).
6. Most of the samples in Tumkur, Taluk fall in the suitable range for irrigation purpose from USSL diagram.

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