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# EVALUATION OF GROUNDWATER SUITABILITY FOR DRINKING AND IRRIGATION – A CASE STUDY OF YADAGIR DISTRICT, KARNATAKA STATE, INDIA

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## ABSTRACT

An investigation has been made to study the ground water suitability in the Yadagir district. Ninety groundwater samples were collected randomly from Yadagir district during pre-monsoon season, 2018. The samples were analyzed for physico-chemical parameters and irrigation quality parameters of sodium absorption ratio (SAR), Percent sodium (%Na) and residual sodium carbonate (RSC) as per Standard Methods. The results indicated that, the pH values of 8.82% of Yadagir, 60% of Shahapur and 87.1 % of Shorapur samples were above the BIS standard limit of 6.5-8.5. The higher level of pH value of groundwater samples was due to higher alkalinity and bicarbonate contents. Around 35% of the samples showed Electrical conductivity above 2000 µS/cm, which can be correlated with high range of TDS values. Among the irrigation parameters, around 8 % samples in Shahapur taluk showed excess SAR values of more than 18 and are unsuitable for irrigation purpose. A very high range of percent sodium values were observed in 34.3, 56 and 45.2 % of samples respectively among the Yadagir, Shahapur and Shorapur taluks and are also classified as unsuitable for irrigation. The RSC values (>1.25 meq/L) were reported for 44.1% (Yadagir), 72% (Shahapur) and 80.6% (Shorapur) of samples, makes these samples unfit for irrigation. Further, WQI values indicated that 65.6 % of the samples were considered as unsuitable for domestic and irrigation purpose, due to higher range of salts / salinity, total hardness, sodium and bicarbonates values.

**KEYWORDS:** Ground water, Salinity, SAR, Water Quality Index, Yadagir district.

## INTRODUCTION

The more pressure on ground water resources was witnessed by extension of domestic and irrigation activities as surface water is getting over polluted and more stringent treatments would be required to make surface water potable.

Although, the depletion of ground water level is also being increased day by day; water level fall of less than 2 m has been recorded in entire Karnataka State in addition to water level fall in the range of 2 to 4 m in all the districts and water level fall of more than 4 m in many districts. Therefore, the intensive use of natural resources and production of wastes in modern society often cause a threat to groundwater quality that have noticed in many incidents of groundwater contamination. These problems are observed in many parts of the country and intern led to the reduction in quality of water as well as the availability of groundwater, besides shrinking their natural restoration capacity due to the impact of climate change. Particularly, contaminants such as heavy metals, pesticides, arsenic, nitrate and fluoride affect the groundwater quality in developing countries.[1] In India, fluoride contamination was noticed for 62 million people among 17 states in India.[2,3] In Karnataka too, about 13% of the samples are in the 'unsuitable' range as the fluoride concentration beyond 1.5 mg/l rendered them unsuitable for drinking especially in parts of Bagalkot, Bijapur, Bellary, Bangalore Urban, Bangalore Rural, Raichur, Koppala, Gadag, Yadgir, Chitradurga, Chikkaballapura, C.R. Nagar, Davanagere, Gulbarga, Haveri, Kolar, Mandya, Uttar Kannada and Tumkur districts.[4] The changes in ground water chemistry is commonly influenced by many factors such as discharge and recharge rate, rate of extraction of ground water, thickness of unsaturated zone, types of aquifers, ground water potential and rate infiltration, etc., in addition to man-made activities.[5,6,7,8]

The water quality is commonly expressed in terms of relative suitability by using water quality index, which is again based on the available water quality standards for intended use. Water quality index is computed to reduce the large amount of water quality data to a mere numerical value that expresses the overall water quality at a certain location and time based on several water quality parameters. The inter-relationship of ground water quality can be easily understood by using WQI having significant applications noticed by many studies.[9,10,11,12] The aim of the present study is to assess the groundwater quality through hydrochemistry and other irrigation parameters for drinking and irrigation purpose in Shahapur, Yadgir and Sholapur taluks of Yadgir district, Karnataka as the area is mainly depend on groundwater source for domestic, irrigation and industrial activities.

## MATERIAL AND METHODS

### Study area

Yadgir District is geographically between $16^0 11'$ – $16^0 50'$ N latitudes and $76^0 17'$ - $77^0 28'$ E longitudes, with a area of 5234.4 Sq.Km. It is located in the North-eastern part of Karnataka state and is surrounded by Kalburgi (Gulbarga) district towards the North, whereas Raichur, Vijayapur (Bijapur) and the state of Telengana in the south, west and east direction respectively. The district comprises of 3 taluks namely, Shahapur, Yadgiri and Shorapur (**Figure 1**). There are16 hoblies, 117 Gram Panchayats, 4 Municipalities,8 Towns/ Urban agglomerations and 487 inhabited and 32 un-inhabited villages. Population of the district was 11.73 lakhs with an average population density of 224 per $KM^2$ (2011 Census).

Yadgir district lies in the northern plains of Karnataka and has semi - arid type of climate. Yadgir district is eastern transition and north eastern dry zone as the climate is generally hot, dry and healthy with the predominance of rain fed dry land agricultural area. December is the coldest month with mean daily maximum and minimum temperatures being $29.5^0$ C and $15^0$ to $10^0$ C respectively. During peak summer, temperature shoots up to $45^0$C. Relative humidity varies from 26% in summer to 62% in winter. The southwest monsoon sets in the middle of June and extends till the end of September. Significant rainfall occurs during the winter monsoon owing to north eastern monsoon, which constitutes 7% of the annual rainfall. Normal Rainfall of the district is 699 mm (2001 - 2010) and actual rainfall is 633 mm (2011).[13]

Geologically, the northern part of the district represents a plateau, typical of Deccan Trap terrain and is deeply indented with ravines. The southern part predominated by Peninsular Gneiss and granites. Central, northeastern and southwestern part comprises of sedimentary formations viz. sandstone, quartzite, shale, slate, limestone and dolomite. Deccan Trap basalts cover eastern parts. Major ground water stored in formations such as granite, gneiss, limestone and vesicular basalt which are weathered, fractured and jointed zones of these formations.[13]

In weathered zones ground water occurs in phreatic condition, whereas in the fractured and jointed formation it occurs in semi-confined to confined condition. A small portion of Deccan Trap basalts, which comprise different flows, fractures and interstitial pore spaces of vesicular zone, are good repositories of ground water. In limestone, solution cavities are considered to be more potential than weathered and fractured zones. Laterite have primary porosity and are considered to be moderately good aquifer. The main source of recharge to ground water is precipitation, followed by seepage from canals and return flow from irrigation.

About 75% of the geographical area of the district is under cultivation. Both Shahapur and Surpur (Shorapur) taluks have been fully irrigational land, while Yadagir Taluka having 65% irrigated area. Agriculture in the district mainly depends upon the rainfall and two main rivers, ‘Krishna’ and ‘Bhima’ along with few tributaries. Kagna and Amarja are the two sub-basins of Bhima River. Irrigation through dug wells is more prevalent in Yadgir taluk, whereas, irrigation in Shorapur and Shahpur taluks is through canal of Upper Krishna Project. Lift Irrigation Schemes are under implementation along Bhima River. The major crops grown in the district are jowar, paddy, red gram, sunflower, groundnut, cotton and sugarcane.

## METHODOLOGY

Ninety groundwater samples spread across three taluks of Yadagir district **(Fig 1)** were collected during February / March 2018. Parameters such as pH, electrical conductivity, TDS were analyzed in the field; the standard methods were followed during collection, transportation and analysis of the remaining parameters of the samples.[14] Before collection of the groundwater samples, the bore / hand pumps were operated for 10 mins to ensuring the collection of representative sample. Based on the physico-chemical analyses and the methodology described elsewhere[15,16,17], groundwater quality was evaluated by calculating water quality index (WQI) using SAR, Percent Sodium and RSC values.

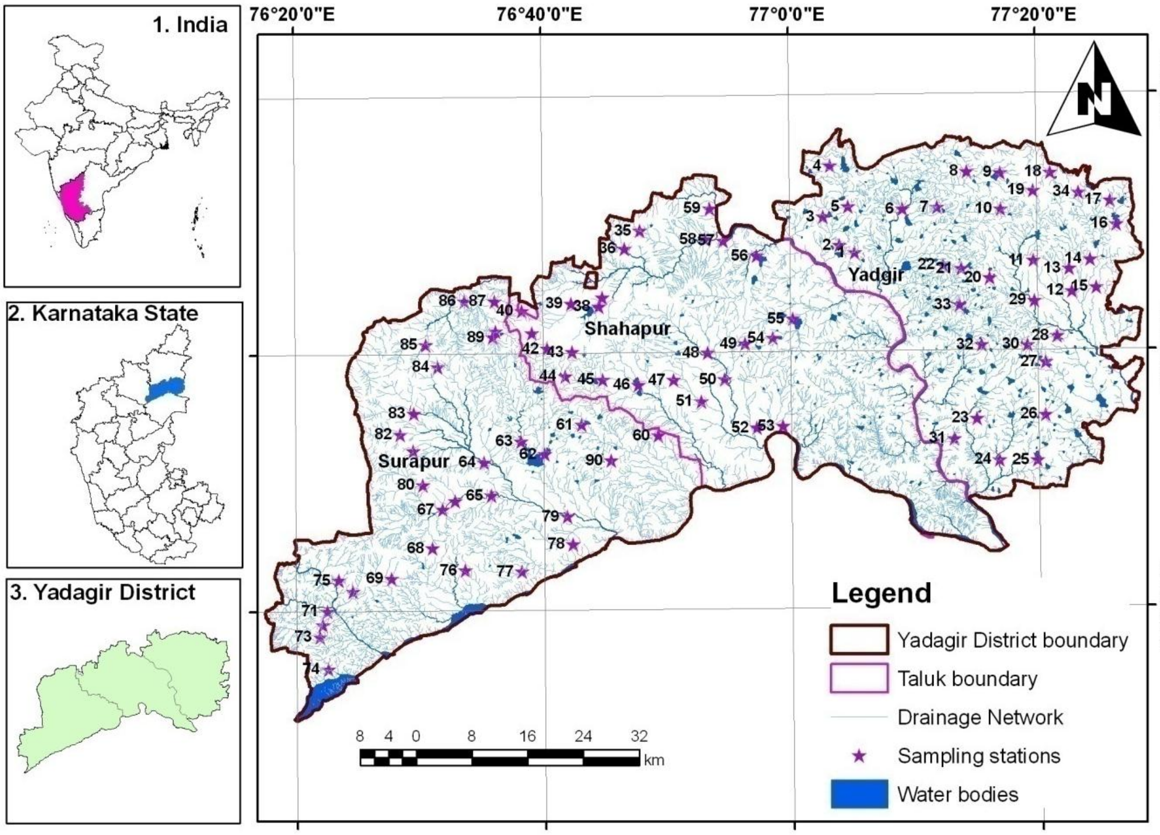


**Fig. 1: Study area map showing location of sampling stations.**

**Sodium Adsorption Ratio (SAR)**

Sodium adsorption ratio (or) sodicity is the measure of relative concentration of sodium with respect to calcium and magnesium in groundwater [18]. The SAR is calculated using the following equation.[19]

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$$

Where all the concentration of ions is expressed in meq/L.

**Residual sodium carbonate (RSC)**

The suitability of groundwater is affected by excess concentration of bicarbonates and carbonates over calcium and magnesium. The excess bicarbonate concentration is harmful to physical properties of soil.[20] The RSC can be calculated by the following formula.[21]

$$\mathrm{RSC} = (\mathrm{Alkalinity} * 0.0333) - (\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})$$

Where all the concentration of ions is expressed in meq/L.

**Soluble Sodium Percentage (Na%)**

Sodium concentration in excess reduces the permeability of soil, destroys the soil structure and affects the drainage of the area which eventually leads to reduction of crop production and plant growth. Na% is calculated using the formula.

$$\%Na = \frac{(Na^{+} + K^{+}) * 100}{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})}$$

Where all the concentration of ions is expressed in meq/L

**Water Quality Index (WQI)**

Water quality index is an important tool which is used to assess the quality and suitability of water for drinking purposes in the urban, rural and industrial areas [22] .WQI is consists of obtaining one value that explains the overall effects of chemical compound effect of individual water quality characteristics for human consumption.[23] By using following steps WQI can be calculated (**Table 1**).

1. Calculation of Sub Index ($q_i$)

$$q_i = \frac{[(V_n - V_{id})]}{[(S_n - V_{id})]} * 100$$

Where

$q_i$ = quality of sub index

$V_n$=estimated value of nth WQ parameter at a given sample location

$V_{id}$=ideal value for nth parameter in pure water (for pH=7 and 0 for all other parameters)

$S_n$=standard permissible value of nth water quality parameter

2. Weight should be assigned for each parameter based on their importance (Wi)

**Table 1: Assigned and Relative weight for WQI computations with BIS standards.**

| Sl. No | Parameters | Sn | Ideal Value (Vid) | Weight (wi) | Relative weight (Wi) |
|---|---|---|---|---|---|
| 1 | pH | 8.5 | 7 | 3 | 0.083 |
| 2 | EC | 2000 | 0 | 3 | 0.083 |
| 3 | TDS | 500 | 0 | 5 | 0.139 |
| 4 | TA | 200 | 0 | 2 | 0.056 |
| 5 | TH | 300 | 0 | 3 | 0.083 |
| 6 | So4 | 200 | 0 | 3 | 0.083 |
| 7 | K | 10 | 0 | 2 | 0.056 |
| 8 | Na | 200 | 0 | 3 | 0.083 |
| 9 | F | 1 | 0 | 5 | 0.139 |
| 10 | Ca | 75 | 0 | 2 | 0.056 |
| 11 | Mg | 30 | 0 | 2 | 0.056 |
| 12 | Cl | 250 | 0 | 3 | 0.083 |
| **Total** | | | | **Σwi = 36** | **ΣWi = 1.000** |

3. Calculation of Relative Weight ($R_{wi}$) using the equation: $\boldsymbol{RW_i = \frac{w_i}{\sum w_i}}$

Where $w_i$= assigned weight of each parameter

4. Calculation of sub index of ith parameter, SIi using the equation: $\boldsymbol{SI_i = q_i * RW_i}$

5. Calculation of WQI using the equation:

$$\boldsymbol{WQI = \sum SI_i}$$

## RESULTS AND DISCUSSION

The Analytical results of the physico-chemical parameters, irrigational quality parameters and WQI for the groundwater samples analyzed are given in **Table 2**.

The pH values indicated that 8.82% of Yadagir, 60% of Shahapur and 87.1 % of Shorapur samples were showed above the BIS standard limit of 6.5-8.5. The higher level of pH value of groundwater samples was due to higher alkalinity and bicarbonate contents. Around 35% of the samples showed Electrical conductivity above 2000 µS/cm, which can be correlated with high range of TDS values

**Table 2: Descriptive statistics showing analytical results for groundwater samples.**

| Category | Parameters | Yadgir (n=34) | | | Shahapur (n=25) | | | Surpur (n=31) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** | **Min** | **Max** | **Mean** |
| General parameters | pH | 7.50 | 8.90 | 8.10 | 7.70 | 9.30 | 8.50 | 8.30 | 9.50 | 8.90 |
| | EC | 575.0 | 5670.0 | 1974.7 | 710.0 | 10520.0 | 2376.4 | 630.0 | 3380.0 | 1700.0 |
| | TDS | 368.0 | 3628.8 | 1263.8 | 360.0 | 5250.0 | 1187.6 | 310.0 | 1680.0 | 847.4 |
| | Hardness | 140.0 | 1150.0 | 460.6 | 170.0 | 2220.0 | 609.2 | 140.0 | 880.0 | 453.8 |
| | Alkalinity | 52.0 | 520.0 | 239.3 | 211.0 | 1204.0 | 447.1 | 215.0 | 699.0 | 420.1 |
| Major cations | $Ca^{2+}$ | 28.0 | 344.0 | 103.5 | 24.0 | 609.0 | 131.9 | 40.0 | 232.0 | 102.6 |
| | $Mg^{2+}$ | 17.1 | 156.2 | 49.2 | 10.0 | 321.0 | 69.0 | 5.0 | 124.0 | 47.9 |
| | $Na^+$ | 30.9 | 470.8 | 142.6 | 50.0 | 2172.0 | 338.7 | 42.7 | 512.0 | 198.2 |
| | $K^+$ | 0.3 | 126.5 | 13.3 | 1.1 | 144.0 | 27.5 | 2.2 | 337.0 | 28.8 |
| Major anions | $Cl^-$ | 20.0 | 1089.7 | 230.2 | 52.0 | 2084.0 | 391.8 | 87.0 | 588.0 | 222.2 |
| | $SO_4^{2-}$ | 21.0 | 368.0 | 165.9 | 31.1 | 2026.0 | 280.1 | 51.2 | 697.0 | 210.4 |
| | $F^-$ | 0.6 | 2.3 | 1.2 | 0.3 | 4.8 | 1.4 | 0.2 | 3.1 | 1.0 |
| | $PO_4^{3-}$ | 0.1 | 0.7 | 0.2 | 0.0 | 0.6 | 0.2 | 0.0 | 0.3 | 0.2 |
| | $HCO_3^-$ | 63.4 | 634.4 | 292.0 | 257.0 | 1469.0 | 545.4 | 262.0 | 852.0 | 512.4 |
| Irrigational quality parameters | SAR | 0.85 | 17.30 | 3.21 | 1.01 | 19.95 | 5.04 | 1.01 | 13.49 | 4.22 |
| | % Na | 15.23 | 87.94 | 38.66 | 18.02 | 77.09 | 43.76 | 18.98 | 82.84 | 42.70 |
| | RSC | -18.26 | 8.99 | -1.25 | -35.42 | 19.72 | 2.63 | -4.17 | 19.74 | 4.93 |
| Drinking water suitability | WQI | 63.80 | 313.08 | 141.50 | 58.58 | 723.34 | 187.18 | 62.57 | 389.62 | 142.94 |

TDS, total hardness, SAR, percent sodium and RSC values indicated that some samples fall in the category of unsuitability for irrigation purpose. Carroll's (1962) classification of groundwater based on TDS indicated that nearly 58.9 % samples were fresh in nature, without any salinity problem (Table 3). Rest all other samples are classified as brackish water, which can neither be used irrigation nor for drinking purpose. Nearly 97.78 % of the samples fall in hard to very hard class based on Sawyer and McCarty's (1967)[24] classification with respect to total hardness (**Table 3**).

Majority of the samples from Yadagir district were classified as suitable for irrigation except for 8 % of the samples from Shahapur taluk as these samples recorded SAR value in excess of 18. Further, green and yellow colour zone in spatial distribution map of SAR values (Fig 2) for Yadagir district depicts major part of the study area is under excellent and good class.

**Table 3: Classification of ground water to evaluate their suitability.**

| Parameter | Range | Remarks on water quality | Pre-monsoon season (n=90) | |
|---|---|---|---|---|
| | | | Range | No. of samples (%) |
| Water salinity classification based on TDS (Carroll, 1962), mg/L | 0–1000<br>1000-10,000<br>10,000-100,000<br>> 100,000 | Fresh water<br>Brackish water<br>Salty water<br>Brine | 310-950<br>1020-5250<br>---<br>--- | 53 (58.88)<br>37 (41.12)<br>---<br>--- |
| TH as $CaCO_3$, mg/L (Sawyer and McCarthy, 1967). | <75<br>75–150<br>150–300<br>>300 | Soft<br>Moderately hard<br>Hard<br>Very hard | ---<br>140<br>170-300<br>310-2220 | ----<br>2 (2.22)<br>22 (24.44)<br>66 (73.34) |
| SAR value (Richards *et al.*,1954) | 0-10<br>10-18<br>18-26<br>>26 | Excellent<br>Good<br>Permissible<br>Unsuitable | 0.85-9.97<br>10.71-17.30<br>19.35-20.05<br>---- | 83 (92.22)<br>5 (5.56)<br>2 (2.22)<br>---- |
| Percent sodium (Eaton , 1950) | <20<br>20-40<br>40-60<br>60-80<br>>80 | Excellent<br>Good<br>Permissible<br>Doubtful<br>Unsuitable | 15.23-19.14<br>20.51-40.00<br>40.92-57.38<br>60.05-77.13<br>82.92-87.94 | 4 (4.44)<br>46 (51.12)<br>22 (24.44)<br>16 (17.78)<br>2 (2.22) |
| Residual Sodium Carbonate, meq/L (Eaton , 1950) | <1.25<br>1.25-2.5<br>>2.5 | Good<br>Doubtful<br>Unsuitable | (-35.42) – 1.23<br>1.44 – 2.39<br>2.51 – 19.74 | 32 (35.56)<br>12 (13.33)<br>46 (51.11) |
| WQI classification (Acharya *et al.*, 2018)[25] | <50 | Excellent | ---- | ---- |
| | 50-100 | Good water | 53.53-97.72 | 31 (34.4) |
| | 100-200 | Poor water | 102.8-195.0 | 46 (51.1) |
| | 200-300 | Very poor | 218.6-299.0 | 8 (8.9) |
| | >300 | Unsuitable for drinking | 334.8-688.0 | 5 (5.6) |

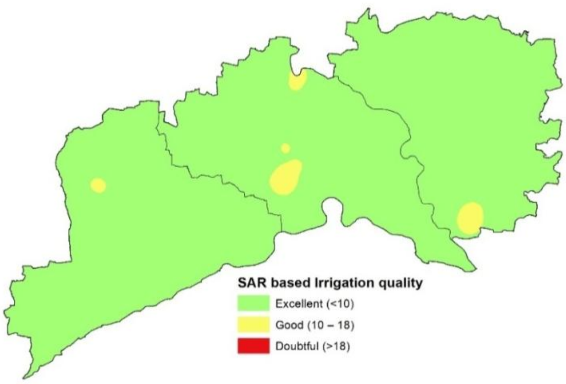


**Fig. 2: Distribution of SAR value in the groundwater samples from study area**

A very high range of percent sodium values were observed among the Yadagir, Shahapur and Shorapur taluks (34.3, 56 and 45.2 % of samples respectively) which are unsuitable for irrigation as per water suitability classification [26]. The higher level of sodium may reduce the permeability and poor internal drainage system because of sodium ions tend to be adsorbed by clay particles, displacing Mg and Ca ions during the exchange of water sodium content with the Calcium and Magnesium content of soil [27]. Further, orange and red colour zone in patches here and there in spatial distribution map of Percent sodium values (Fig 3) for Yadagir district illustrates the areas harboring bore wells whose water quality is unsuitable for irrigation.

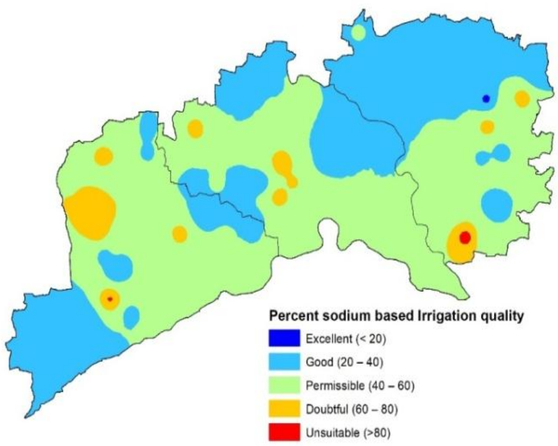


**Fig 3: Distribution of Percent Sodium in the groundwater samples from study area.**

According to the US Department of Agriculture, water having >2.50 epm of RSC values is not suitable for irrigation purposes. In the study area, the RSC values for 44.1% (Yadagir), 72% (Shahapur) and 80.6% (Shorapur) of samples exceeded 1.25 meq/L and are classified as unsuitable for irrigation. As per spatial distribution map of RSC values (Fig 4) for Yadagir district, major part of Surpur taluk, some part of Shahapur and Yadagir taluks (appear as red colour patches) represents zones with groundwater samples unsuitable for irrigation.

WQI values indicated that 65.6 % of the samples were considered as unsuitable for domestic and irrigation purpose (Table 2), due to higher range of salts / salinity, total hardness, sodium and bicarbonates values. Further, yellow, orange and red colour zone in Spatial distribution map of WQI values (Fig 5) for Yadagir district illustrates that major part of the study area is having poor quality groundwater that can be neither be used for drinking purpose nor for irrigation purpose. This could be due to overexploitation and other activities discharges from agricultural and domestic uses.

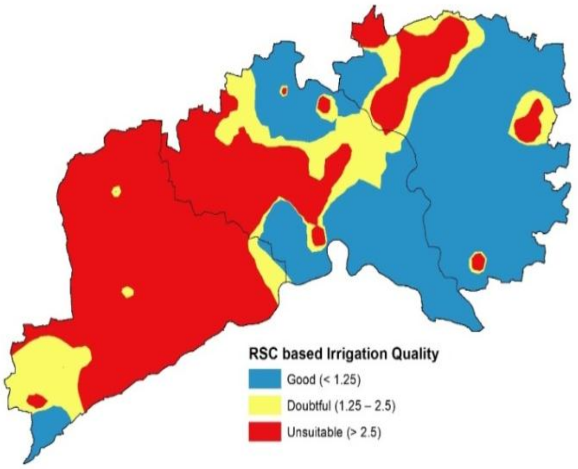


**Fig 4: Distribution of RSC in the groundwater samples from study area.**

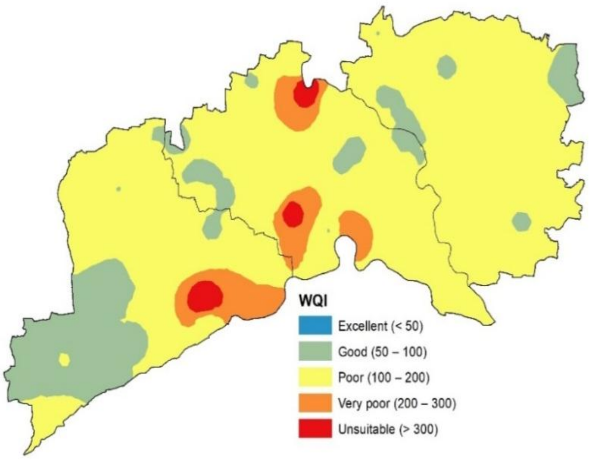


**Fig 5: Distribution of WQI value in the groundwater samples from study area.**

## CONCLUSION

The highest percent samples in Shahapur (60%) and Shorapur (87.1%) were showed the pH values above the BIS standard limit of 6.5-8.5. The higher level of pH value of groundwater samples was due to higher alkalinity and bicarbonate contents. Around 35% of the samples were showed above 2000 µS/cm Electrical conductivity values which were correlated with high range of TDS values. The irrigation parameters, around 8% samples were exceeding 18 mg/L SAR values in Shahapur taluk, which are unsuitable for irrigation purpose and remaining samples were found to be suitable for irrigation. The very high range of percent sodium values were observed among the Yadagir, Shahapur and Shorapur taluks (34.3, 56 and 45.2 % of samples respectively) which are unsuitable for irrigation. Around 44.1% (Yadagir), 72% (Shahapur) and 80.6% (Shorapur) of samples were exceeding the RSC values of 1.25 meq/L. The higher range of RSC in water will influence to increase in the adsorption of sodium in soil.[21] WQI values indicated that 65.6 % of the samples were considered as unsuitable for domestic and irrigation purpose, due to higher range of salts / salinity, total hardness, sodium and bicarbonates values

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