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# Groundwater Quality Assessment for Domestic and Irrigational Suitability in Kallada River Basin, South Kerala, India

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## ABSTRACT

Physico-chemical assessment of drinking water quality as well as agricultural utility of Kallada River Basin, Kerala has been done in various stations for post-monsoon (August 2010) and pre-monsoon (April 2011) seasons. The open well samples were collected from the 107 wells around this region and analysed for pH, EC, TDS, major cations and anions. The results were evaluated and compared with BIS water quality standards. Majority of the samples is showing an acidic pH, making only 10% samples of post-monsoon and 17% samples of pre-monsoon suitable for human consumption. Except pH all other parameters are within the permissible limit of BIS. The irrigational parameters like EC, SAR values, %Na and RSC have been worked out to know the suitability of the groundwater for irrigational purpose. The USSL diagram for the post-monsoon and pre-monsoon seasons depicts that the water has low to medium salinity hazard and low sodium hazard. According to the classification of Wilcox (1955) most of the samples for both the seasons are safe for irrigation. The RSC values are predominantly negative, indicating that sodium builtup is unlikely, since sufficient calcium and magnesium is in excess of what can be precipitated as carbonates. The overall quality of the water in the study area is suitable for drinking and irrigation purpose.

## INTRODUCTION

Water is the basic necessity for the existence of human society. It is one of the most important components of the environment and an integral part of the ecological cycle. Groundwater is being increasingly recognized as a dependable resource to meet the demands of domestic, irrigation and industrial sectors all over the world. There has been a tremendous increase in the demand for freshwater due to the rapid escalation in population. Because of an easy access to groundwater, people are exploiting the resource indiscriminately. Lack of sanitation, improper waste disposal, faulty well construction and lack of water resource protection measures, increase the groundwater contamination and this has resulted in the depletion of groundwater reserves. In this context it is necessary to ascertain the potability of water before it is used for human consumption. Groundwater quality is defined based on a set of health and safety regulations for domestic use. The study of groundwater quality involves the description of the occurrence of various constituents in groundwater and the relation of these constituents to water use (Mahajan 2009). In the present study, an attempt is made to evaluate the physico-chemical characteristics of groundwater in Kallada River Basin, South Kerala, India.

## STUDY AREA

Kallada River Basin (KRB) has been selected as the study area which is located between north latitudes 8°44'12.9" and 9°10'36.3" and east longitudes 76°3'44.8" and 77°15'47.5". The basin is elongated in shape and has an area of about 1700 $km^2$ which is situated in both, Kollam and Pathanamthitta districts of the State of Kerala. The basin has the distinction of having all the major physiographic units (coastal plain 0-10 m; lowland 10-300 m; midland 300-600 m; highland 600-800 m) discerned in Kerala. Drainage pattern is dendritic and in most cases, structural control is amplified by a trellis pattern and straightness of the stream course (Suma et al. 2011). Two Ramsar sites, Ashtamudi Lake and Sasthamkota Lake are located in the study area. The river originating from the Western Ghats drains into Ashtamudi backwaters near Kollam. The rainfall in this region is mostly due to south-west monsoon (June-September) and the annual rainfall in the basin is 2428 mm (CGWB 2013).

## MATERIALS AND METHODS

The base map was prepared using toposheet numbers 58C/12, 58C/16, 58D/9, 58D/13, 58G/4 and 58H/1 on 1:50,000 scale. Groundwater samples were collected from 107 open wells located in Kallada River Basin (KRB) during the post-monsoon (August 2010) and pre-monsoon period (April 2011). The location of groundwater sampling stations is shown in (Fig. 1). The wells from which samples were collected are extensively used for drinking and other domestic

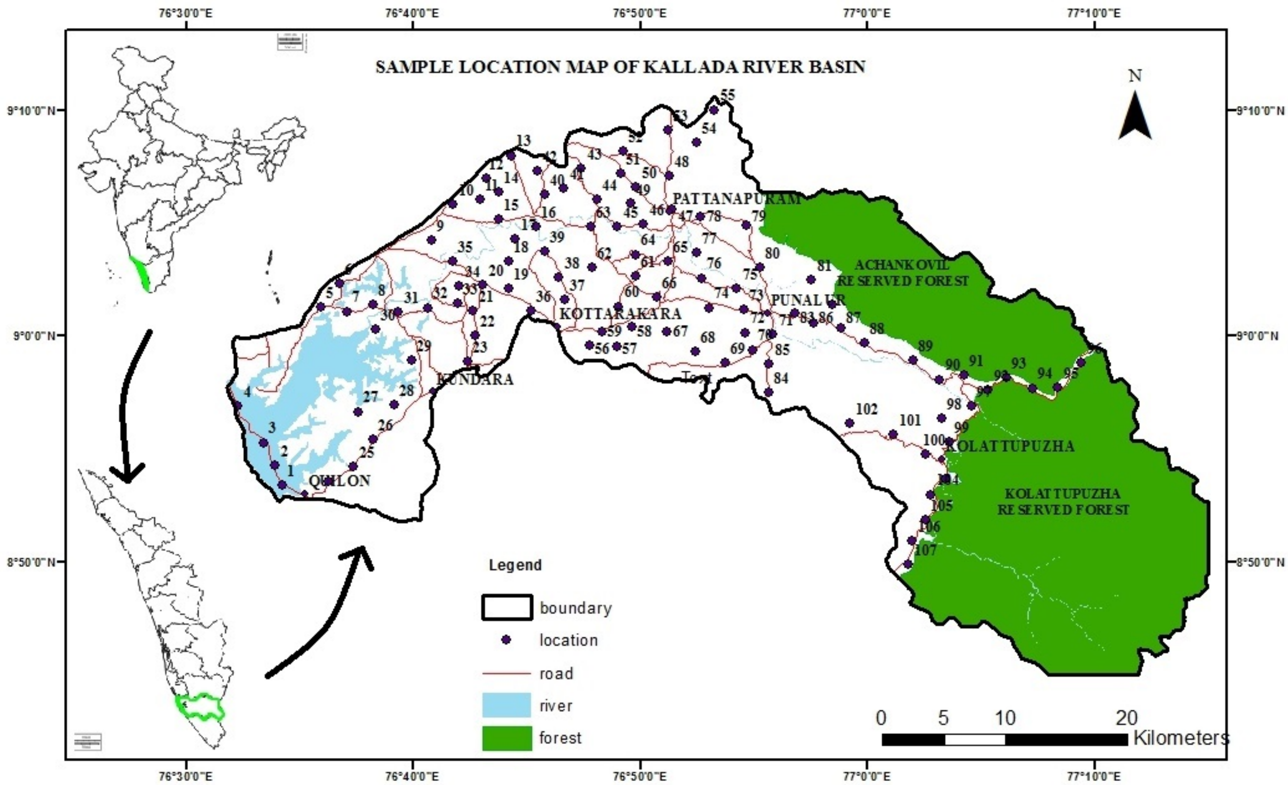


Fig. 1: Groundwater sample location map.

purposes. The samples were analysed to detect calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, phosphate, sulphate, nitrate, pH, electrical conductivity, total hardness, salinity and total dissolved solids. All the physico-chemical parameters mentioned above were determined by recommended procedures in standard methods (APHA 1985). All concentrations are expressed in ppm. The results obtained are compared with drinking water quality standards (BIS 1992). The suitability of the samples for irrigational purpose was also determined.

## RESULTS AND DISCUSSION

**Suitability for domestic use:** To ascertain the suitability of groundwater for drinking and public health purposes, hydrochemical parameters of the samples are compared with the guidelines recommended by BIS (Table 1). The pH of groundwater samples varies between 4 to 7.4 (mean 5.2) and 4.4 to 7.7 (mean 5.2) during the post and pre monsoon season respectively. Based on pH, only 10% of post-monsoon and 17% of pre-monsoon samples were found suitable for drinking purpose as per BIS standards. Most of the samples have pH value below 6.5 which is considered too acidic and consumption of this acidic water can cause gastrointestinal disorders like hyper acidity, ulcers, stomach pain and burning sensation (Rajesh et al. 2001). In a natural environment, the pH goes towards the acidic range due to dissolved carbon dioxide and organic acids (e.g. fulvic and humic acids) derived from decay and subsequent leaching of plant materials (Gracia et al. 2001). Excessive use of fertilizers and presence of lateritic aquifer can also be the reason for acidic pH in shallow groundwater. Conductivity values vary from 17.5 µS/cm to 624 µS/cm (mean 172 µS/cm) in post-monsoon and 29.25 µS/cm to 916.5 µS/cm (mean 194.75 µS/cm) in pre-monsoon season. The EC values are higher in pre-monsoon than post monsoon. The slight increase and decrease in EC is due to concentration and rain fed dilution during pre and post-monsoon. The TDS value ranges from 10.5 ppm to 374.0 ppm during post-monsoon and 17.5 ppm to 549.6 ppm during pre-monsoon. TDS value for post-monsoon samples is within desirable limit recommended by BIS, but sample from location 1 shows TDS value above 500 ppm in pre-monsoon. The TH of groundwater varies from 20 ppm to 255 ppm (mean 60 ppm) in post-monsoon and 10 ppm to 275 ppm (mean 48 ppm) in pre-monsoon. Groundwater exceeding the limit of 300 ppm of TH is considered to be very hard (Sawyer et al. 2003). The

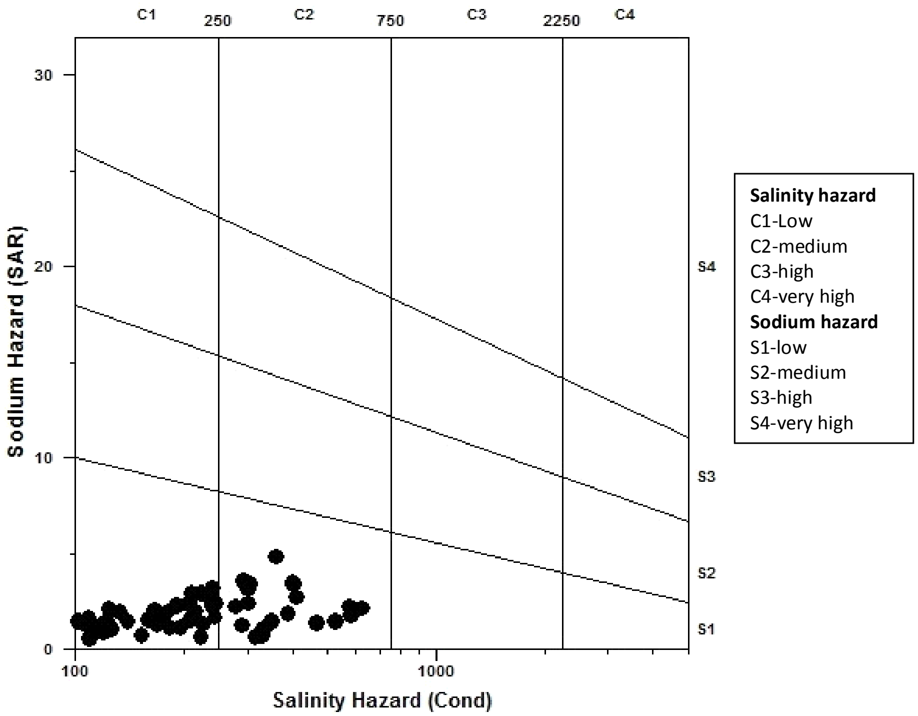


Fig. 2: Classification of groundwater based on US salinity diagram for post-monsoon season.

Table 1: Comparison of chemical constituents of groundwater samples from the study area with BIS drinking water quality standards.

| Parameters | Post-monsoon | | | Pre-monsoon | | | Highest | Maximum |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Average | Min | Max | Average | desirable | permissible |
| pH | 4 | 7.4 | 5.2 | 4.4 | 7.7 | 5.8 | 6.5-8.5 | No relaxation |
| EC (ìS/cm) | 17.5 | 624 | 172 | 29.2 | 916 | 194.7 | 1500 | 3000 |
| TDS ppm | 10.5 | 374 | 103.2 | 17.5 | 549.6 | 116.8 | 500 | 2000 |
| TH ppm | 20 | 255 | 60 | 10 | 275 | 48 | 300 | 600 |
| Ca ppm | 2 | 58.1 | 9.7 | 2 | 62.1 | 9.4 | 75 | 200 |
| Mg ppm | 3.6 | 27.9 | 8.7 | 1.2 | 29.‘ | 6 | 30 | 100 |
| Na ppm | 3 | 72 | 23.7 | 1 | 76 | 17.6 | - | - |
| K ppm | 0 | 36 | 4.5 | 1 | 21 | 3.9 | - | - |
| Cl ppm | 10.7 | 106.5 | 37.4 | 7.1 | 142 | 31.2 | 250 | 1000 |
| $HCO_3$ ppm | 5 | 265 | 28 | 5 | 110 | 17.6 | - | - |
| $SO_4$ ppm | 0.2 | 75 | 6.4 | 4.8 | 199.8 | 19.6 | 200 | 400 |
| $NO_3$ ppm | 0 | 6.2 | 2.4 | 0 | 20.8 | 5.7 | 45 | 100 |
| $PO_4$ ppm | 0 | 0.7 | 0.01 | 0 | 3.2 | 0.05 | - | - |

result indicates that none of the water samples falls in the very hard category and above the desirable limit recommended by BIS.

Among the cations, Na is the dominant cation and it ranges from 3 ppm to 72 ppm (mean 23.7 ppm) and 1 ppm to 76 ppm (mean 17.6 ppm) during the post-monsoon and pre-monsoon seasons respectively. It is followed by Ca which ranges from 2 ppm to 58.1 ppm during the post-monsoon and 1.2 ppm to 29 ppm during pre-monsoon. The concentration of other cations like Mg and K falls well within the permissible limit recommended by BIS. $SO_4$ is the dominant anion in the water samples ranging from 0.2 ppm to 75 ppm and 4.84 ppm to 199.8 ppm during post-monsoon and pre-monsoon seasons respectively. The carbonates and bicarbonates in water are present mainly in association with $Ca^{2+}$ and $Mg^{2+}$ (Rout & Sharma 2011). $HCO_3$ varies from 5 ppm to 265 ppm during post-monsoon, and 5 ppm to 110 ppm during pre-monsoon season. The Cl value ranges from

Table 2: Chemical characteristics of groundwater for irrigation purpose.

| No. | SAR | | % Na | | RSC | | No. | SAR | | % Na | | RSC | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | post | pre | post | pre | post | pre | | post | pre | post | pre | post | pre |
| 1 | 1.89 | 1.99 | 41.90 | 40.18 | 0.25 | -3.69 | 55 | 0.51 | 0.55 | 32.06 | 31.86 | -0.54 | -0.64 |
| 2 | 1.42 | 0.94 | 33.97 | 31.98 | -2.80 | -1.67 | 56 | 2.38 | 2.21 | 62.01 | 58.58 | -0.64 | -1.01 |
| 3 | 2.70 | 3.20 | 54.33 | 68.30 | -1.80 | -0.79 | 57 | 1.13 | 0.96 | 54.19 | 62.30 | -0.25 | -0.12 |
| 4 | 0.60 | 1.63 | 17.60 | 40.96 | -1.82 | -1.83 | 58 | 0.96 | 0.44 | 50.22 | 34.97 | -0.34 | -0.34 |
| 5 | 2.27 | 3.39 | 59.77 | 77.77 | -1.05 | -0.42 | 59 | 0.81 | 0.96 | 45.36 | 53.77 | -0.54 | -0.42 |
| 6 | 0.45 | 0.78 | 19.52 | 48.31 | -1.65 | -0.32 | 60 | 0.95 | 1.12 | 47.74 | 61.86 | -0.44 | -0.14 |
| 7 | 1.08 | 1.32 | 33.10 | 35.00 | -1.58 | -3.18 | 61 | 1.97 | 1.13 | 59.52 | 56.26 | -0.67 | -0.34 |
| 8 | 1.22 | 1.78 | 35.31 | 43.11 | -1.78 | -2.19 | 62 | 1.43 | 1.19 | 59.63 | 55.74 | -0.44 | -0.44 |
| 9 | 1.52 | 3.66 | 51.57 | 79.22 | -1.04 | 0.48 | 63 | 2.48 | 2.07 | 67.94 | 67.29 | -0.64 | -0.44 |
| 10 | 0.66 | 1.02 | 24.52 | 34.13 | -1.05 | -1.64 | 64 | 1.10 | 1.27 | 50.15 | 60.68 | -0.54 | -0.24 |
| 11 | 0.52 | 0.79 | 29.35 | 52.42 | -0.74 | -0.05 | 65 | 1.25 | 1.48 | 55.36 | 62.76 | -0.45 | -0.42 |
| 12 | 2.93 | 2.34 | 67.69 | 73.71 | -0.69 | -0.24 | 66 | 3.17 | 1.75 | 75.29 | 67.83 | -0.47 | -0.35 |
| 13 | 1.10 | 1.39 | 49.16 | 60.75 | -0.55 | -0.34 | 67 | 1.97 | 1.75 | 61.13 | 64.42 | -0.84 | -0.44 |
| 14 | 3.18 | 1.83 | 71.98 | 64.26 | -0.65 | -0.35 | 68 | 0.87 | 0.87 | 49.33 | 48.09 | -0.25 | -0.44 |
| 15 | 0.55 | 0.39 | 33.30 | 33.31 | -0.55 | -0.24 | 69 | 1.59 | 1.57 | 61.23 | 64.59 | -0.44 | -0.34 |
| 16 | 1.03 | 1.24 | 47.57 | 62.73 | -0.45 | -0.14 | 70 | 1.51 | 1.91 | 64.36 | 66.15 | -0.44 | -0.52 |
| 17 | 0.55 | 0.52 | 29.46 | 29.36 | -0.43 | -0.49 | 71 | 0.96 | 0.81 | 47.08 | 44.26 | -0.55 | -0.54 |
| 18 | 2.89 | 2.61 | 71.77 | 74.15 | -0.47 | -0.34 | 72 | 2.00 | 1.31 | 63.05 | 53.06 | -0.64 | -0.47 |
| 19 | 1.75 | 0.60 | 50.00 | 33.32 | -2.44 | -0.98 | 73 | 1.12 | 2.06 | 47.78 | 65.81 | -0.93 | -0.37 |
| 20 | 1.65 | 1.58 | 50.91 | 59.10 | -1.43 | -0.63 | 74 | 0.74 | 0.95 | 41.00 | 51.02 | -0.45 | -0.52 |
| 21 | 0.68 | 0.22 | 29.23 | 20.12 | -0.94 | -0.71 | 75 | 1.09 | 1.56 | 42.09 | 48.31 | -0.82 | -1.03 |
| 22 | 0.84 | 1.17 | 37.82 | 49.61 | -0.87 | -0.49 | 76 | 2.36 | 1.65 | 62.29 | 65.03 | -1.04 | -0.34 |
| 23 | 0.97 | 1.19 | 45.64 | 54.90 | -0.74 | -0.44 | 77 | 1.29 | 1.70 | 49.68 | 55.84 | -0.94 | -0.93 |
| 24 | 1.03 | 0.92 | 31.69 | 30.30 | -2.09 | -1.89 | 78 | 0.79 | 0.56 | 43.45 | 37.24 | -0.44 | -0.52 |
| 25 | 1.36 | 0.90 | 35.91 | 30.15 | -1.50 | -2.00 | 79 | 0.64 | 0.70 | 31.83 | 37.28 | -1.14 | -1.17 |
| 26 | 2.21 | 4.68 | 57.68 | 79.16 | -0.92 | -0.64 | 80 | 0.96 | 1.13 | 51.47 | 56.26 | -0.25 | -0.34 |
| 27 | 1.47 | 1.91 | 56.15 | 71.85 | -0.54 | -0.22 | 81 | 0.89 | 1.03 | 43.56 | 51.72 | -0.72 | -0.44 |
| 28 | 1.45 | 2.41 | 38.55 | 58.53 | -1.01 | -1.17 | 82 | 0.26 | 0.44 | 18.17 | 32.74 | -0.57 | -0.34 |
| 29 | 2.07 | 2.20 | 65.87 | 78.32 | -0.27 | -0.04 | 83 | 1.40 | 1.39 | 57.71 | 62.26 | -0.45 | -0.34 |
| 30 | 0.70 | 0.90 | 31.40 | 39.21 | -0.68 | -0.79 | 84 | 0.49 | 0.52 | 27.22 | 30.75 | -0.67 | -0.57 |
| 31 | 2.12 | 1.35 | 44.21 | 34.73 | -1.93 | -2.59 | 85 | 1.45 | 0.74 | 55.97 | 38.47 | -0.31 | -0.59 |
| 32 | 1.83 | 1.12 | 46.81 | 40.27 | -1.19 | -1.02 | 86 | 0.61 | 0.58 | 39.79 | 43.86 | -0.34 | -0.24 |
| 33 | 0.28 | 0.18 | 21.98 | 15.38 | -0.64 | -0.84 | 87 | 1.35 | 1.35 | 58.40 | 66.64 | -0.35 | -0.14 |
| 34 | 0.89 | 0.51 | 42.51 | 25.80 | -0.55 | -1.04 | 88 | 0.66 | 0.67 | 38.76 | 52.98 | -0.54 | -0.14 |
| 35 | 2.89 | 3.02 | 71.25 | 74.82 | -0.64 | -0.52 | 89 | 0.44 | 0.17 | 32.73 | 18.39 | -0.34 | -0.42 |
| 36 | 3.40 | 2.41 | 70.80 | 68.69 | -0.89 | -0.47 | 90 | 0.41 | 0.45 | 26.39 | 39.98 | -0.55 | -0.14 |
| 37 | 4.82 | 3.31 | 79.88 | 77.60 | -0.55 | -0.42 | 91 | 0.34 | 0.24 | 21.39 | 20.66 | -0.55 | -0.44 |
| 38 | 2.21 | 1.79 | 56.08 | 54.55 | -1.37 | -1.24 | 92 | 0.29 | 0.17 | 24.62 | 21.66 | -0.24 | -0.34 |
| 39 | 0.88 | 1.56 | 45.05 | 65.92 | -0.45 | -0.24 | 93 | 1.31 | 0.34 | 47.12 | 25.70 | -1.17 | -0.87 |
| 40 | 1.18 | 1.13 | 54.85 | 57.21 | -0.29 | -0.34 | 94 | 0.62 | 0.49 | 34.29 | 46.37 | -0.47 | -0.15 |
| 41 | 0.56 | 0.64 | 27.76 | 38.40 | -1.03 | -0.44 | 95 | 0.87 | 0.08 | 49.21 | 10.33 | -0.35 | -0.52 |
| 42 | 1.35 | 1.48 | 56.88 | 62.04 | -0.27 | -0.34 | 96 | 0.80 | 0.05 | 37.17 | 4.71 | -0.51 | -0.66 |
| 43 | 0.70 | 0.59 | 35.27 | 34.82 | -0.69 | -0.45 | 97 | 0.58 | 0.11 | 32.99 | 18.73 | -0.74 | -0.14 |
| 44 | 1.49 | 1.22 | 54.50 | 56.93 | -0.57 | -0.34 | 98 | 0.87 | 0.17 | 48.08 | 21.67 | -0.35 | -0.25 |
| 45 | 3.37 | 2.76 | 72.66 | 67.91 | -0.65 | -0.93 | 99 | 1.03 | 0.24 | 49.40 | 25.69 | -0.64 | -0.52 |
| 46 | 0.44 | 0.49 | 30.34 | 40.21 | -0.25 | -0.24 | 100 | 1.04 | 0.06 | 46.23 | 5.92 | -0.33 | -0.52 |
| 47 | 2.28 | 2.55 | 68.60 | 70.29 | -0.45 | -0.64 | 101 | 1.23 | 0.24 | 49.31 | 17.76 | -0.75 | -1.43 |
| 48 | 1.03 | 1.17 | 47.71 | 58.92 | -0.47 | -0.32 | 102 | 3.58 | 0.45 | 75.72 | 29.32 | -0.64 | -1.33 |
| 49 | 0.39 | 0.55 | 25.77 | 49.98 | -0.74 | -0.04 | 103 | 1.91 | 0.21 | 64.28 | 16.49 | -0.54 | -1.24 |
| 50 | 0.81 | 0.90 | 43.10 | 57.12 | -0.54 | -0.14 | 104 | 0.70 | 0.05 | 41.06 | 4.71 | -0.34 | -1.32 |
| 51 | 3.48 | 2.28 | 71.30 | 64.50 | -0.79 | -0.67 | 105 | 2.35 | 0.30 | 62.31 | 19.48 | -0.85 | -1.83 |
| 52 | 0.89 | 1.12 | 44.56 | 63.08 | -0.64 | -0.14 | 106 | 2.40 | 0.15 | 65.56 | 12.15 | -0.82 | -1.33 |
| 53 | 0.66 | 0.88 | 40.10 | 53.95 | -0.54 | -0.32 | 107 | 1.54 | 0.10 | 54.35 | 8.44 | -0.75 | -1.33 |
| 54 | 0.41 | 0.39 | 26.39 | 36.04 | -0.64 | -0.32 | | | | | | | |

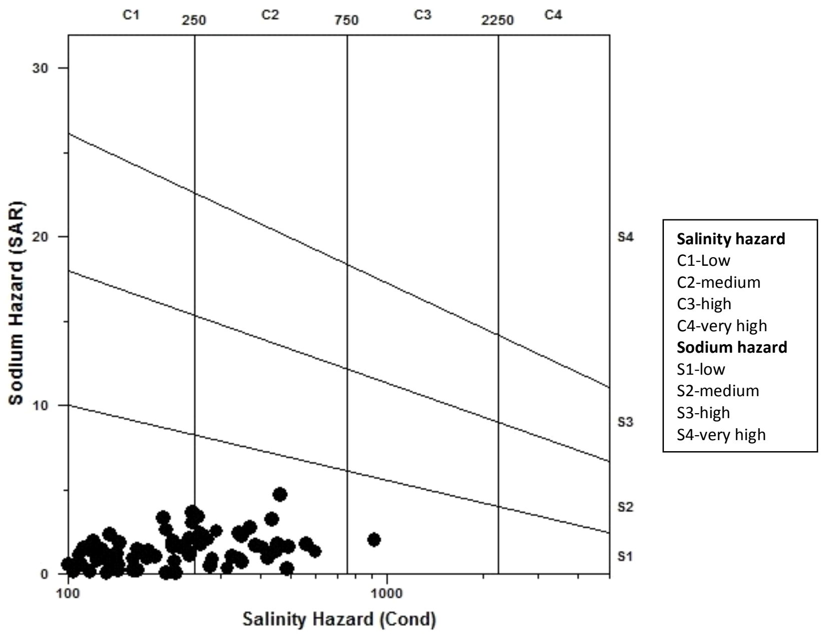


Fig. 3: Classification of groundwater based on US Salinity diagram for pre-monsoon season.

10.7 ppm to 106.5 ppm and 7.1 ppm to 142 ppm during post-monsoon and pre-monsoon respectively. The $NO_3$ and $PO_4$ concentration is very less during both the seasons, which indicate that the groundwater has been less affected by nitrate and phosphate.

**Irrigational water quality:** Good quality irrigation water is essential for achieving maximum crop productivity. EC and $Na^+$ play a vital role in suitability of water for irrigation. Higher EC in water creates a saline soil. The salts apart from affecting the growth of plants also affect the soil structure, permeability and aeration which indirectly affect plant growth (Ackah et al. 2011). Sodium adsorption ratio (SAR), ratio of dissolved sodium (RDS) as % Na, or residual sodium carbonate (RSC) was estimated to assess the suitability of groundwater for irrigation purpose (Table 2).

***Sodium adsorption ratio (SAR):*** Sodium adsorption ratio (SAR) is an important parameter for determination of suitability of groundwater for irrigation purpose. It can indicate the degree to which irrigation water tends to enter into cation exchange reactions in soil (Ahamed et al. 2013).

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

Where Na, Ca and Mg are in milliequivalent per litre. The water quality classification of the study area based on EC and SAR is presented in Table 3.

SAR values of the groundwater in the area under study vary from 0.26 to 4.8 for post monsoon and from 0.05 to 4.6 during pre-monsoon. When the SAR values are greater than 9, irrigation water will cause permeability problems (Saleh et al. 1999). The SAR values of all the samples are in excellent category for both the seasons. The US salinity laboratory classification on the basis of EC and SAR is given in Table 2. According to this classification the EC values of 79.4% samples for post-monsoon season and 73.8% of pre-monsoon season fall in excellent category for agricultural utility. None of the water samples is found unsuitable for irrigational purpose.

For more detailed analysis, the US salinity diagram was prepared (Fig. 2 and Fig. 3). The US salinity Lab's diagram (US Salinity Lab Staff 1954) is widely used for rating irrigation waters, where SAR is plotted against EC. The USSL diagram for the post-monsoon season depicts that the groundwater of the area falls in C1S1 (79.5%) and C2S1 (20.5%) class. The pre-monsoon water samples fall in C1S1 (72.9%), C2S1 (26.2%) and C3S1 (0.9%) class. C1S1 (low salinity-low sodium water) class of water could be used for irrigation on most crops in most soils with little likelihood that soil salinity will develop and with little danger of developing harmful levels of sodium. C2S1 (medium salinity-low sodium water) class of water could be used if a moderate amount of leaching occurs with little danger of developing harmful levels of sodium (Khan & Abbasi 2013). C3S1 (high

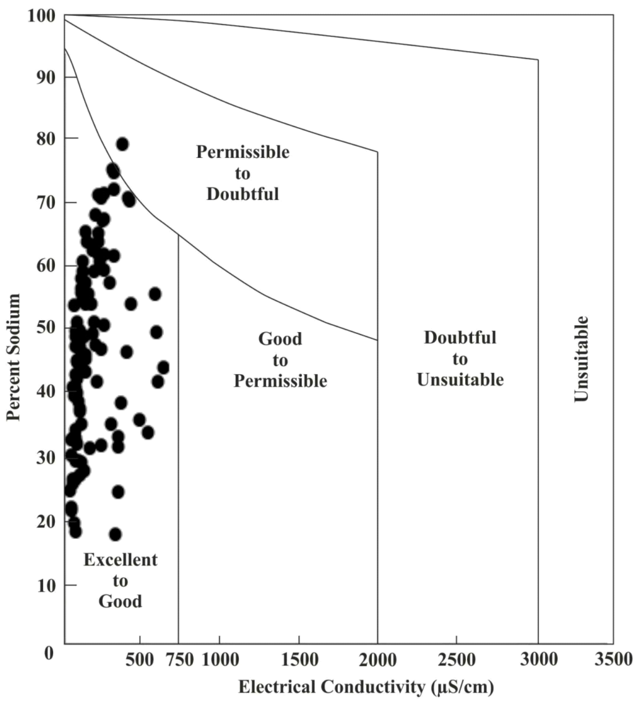


Fig. 4: Classification of groundwater based on Wilcox diagram for post-monsoon season.

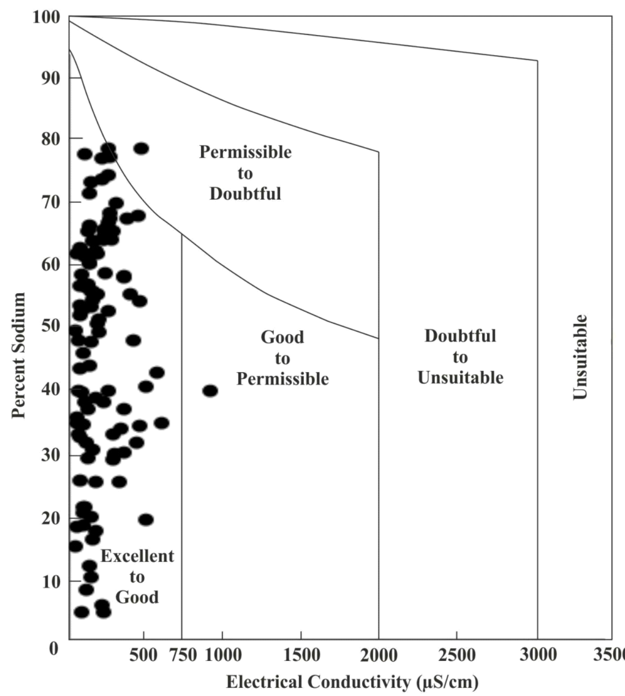


Fig. 5: Classification of groundwater based on Wilcox diagram for pre-monsoon season.

salinity-low sodium water) class of water is considered to be of moderate quality to irrigate semi tolerant crops (Ahamed et al. 2013). This suggests that the groundwater of the area is good for irrigation purpose.

***Percentage of sodium (Na)*:** Sodium content is usually expressed in terms of percent sodium or soluble sodium percentage. The sodium % in water is calculated by

$$\%Na = \frac{(Na+K)}{(Ca+Mg+Na+K)} \times 100$$

Where Ca, Mg, Na and K are expressed in ppm. The Indian standards suggest maximum of 60% sodium is permissible for irrigation water (Table 4).

According to the classification of Wilcox (1955), most of the samples for both post and pre-monsoon seasons are safe for irrigation. Only 22 samples of post-monsoon and 33 samples of pre-monsoon are found in doubtful category for irrigation (Fig. 4).

Wilcox (1955) suggested a graphical method for knowing the suitability of water for irrigation purposes where percent sodium is plotted against electrical conductivity. The plot shows that for post-monsoon season maximum numbers of samples (99.1%) are in excellent to good category and one sample in permissible to doubtful category. Most of the samples of pre-monsoon season (98.2%) fall in excellent to good, 1 sample in good to permissible, and 1 in permissible to doubtful category (Fig. 5). Overall, the groundwater in the study area is suitable for irrigation.

***Bicarbonate hazard:*** Bicarbonate hazard is usually expressed in terms of RSC (Residual Sodium Carbonate). Eaton (1950) calculated residual sodium carbonate (RSC) index as follows:

$$RSC = [HCO_3 + CO_3] - [Ca + Mg];\ \text{expressed in meq/L}$$

A negative RSC indicates that sodium buildup is unlikely since sufficient calcium and magnesium are in excess of what can be precipitated as carbonates. A positive RSC indicates that sodium buildup in the soil is possible. Groundwater could be classified based on RSC as good (< 1.25), doubtful (1.25-2.5) and unsuitable (> 2.5). In the study area, all the water samples for both the seasons are found good for irrigation as per the RSC values.

## CONCLUSION

The water in KRB for both the seasons, except pH, lies within the permissible limit recommended by BIS. Majority of the samples record values lower than the minimum pH prescribed for drinking water. This will lead to acidity in groundwater. Consumption of this acidic water can cause gastrointestinal disorders like hyper acidity, ulcers, stomach pain and burning sensation. Hence a proper acid neu-

Table 3: Water quality classification (U S Salinity Laboratory 1954).

| Quality of water | EC(μS/cm) | Salinity class | % of samples | | SAR (epm) | Sodium class | % of samples | |
|---|---|---|---|---|---|---|---|---|
| | | | Post-monsoon | Pre-monsoon | | | Post-monsoon | Pre-monsoon |
| Excellent | Up to 250 | C1 | 79.4 | 73.8 | Up to 10 | S1 | 100 | 100 |
| Good | 250-750 | C2 | 20.6 | 25.2 | 10-18 | S2 | 0 | 0 |
| Doubtful | 750-2250 | C3 | 0 | 1 | 18-26 | S3 | 0 | 0 |
| Unsuitable | >2250 | C4 | 0 | 0 | >26 | S4 | 0 | 0 |

Table 4: Suitability of groundwater for irrigation use based on % Na after Wilcox (1955).

| % Na | Category | Number of samples (post-monsoon) | Number of samples (pre-monsoon) |
|---|---|---|---|
| <20 | Excellent | 3 | 12 |
| 20-40 | Good | 31 | 29 |
| 40-60 | Permissible | 51 | 33 |
| 60-80 | Doubtful | 22 | 33 |
| >80 | Unsafe | 0 | 0 |

tralizing mechanism needs to be adopted to overcome this problem. The TDS value of location 1 during pre-monsoon season is above the highest desirable limit (500 ppm) of BIS, but within the maximum permissible limit. The dominant cation is Na and the dominant anion is $SO_4$. Higher concentration of major cations and anions are observed near the coastal region when compared to midlands and highland regions. The suitability of water for irrigation is evaluated based on SAR, %Na, RSC and salinity hazards. As per the SAR and RSC classification, all the groundwater samples were found to be excellent for irrigation purpose for both the seasons. The waters have low to medium salinity hazard and low sodium hazard. The Wilcox diagram for both, post-monsoon and pre-monsoon seasons, reveals that the majority of the samples fall in excellent to good category and only very few samples, plot on good to permissible categories and permissible to doubtful category.

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