**Assessment of Water Quality for Varada River Basin using Water Quality Index in Shimoga, Karnataka, India**

**ABSTRACT**

The study is focused on assessment of drinking water quality using water quality index (WQI),for this study purpose used twelve water quality parameters like, pH, Electrical Conductivity, Total Dissolved Solids, Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride, Sulphate and Nitrate and analyzed for pre-monsoon and post-monsoon seasons at Varada river basin from the year 2005 to 2008. The result was found that the most of the water samples having “Good” category for drinking purposes for both seasons. According to BIS standards all samples comes under within the permissible limit except few samples due to urban runoff, anthropogenic activities and more use of chemical fertilizers.

**Key words:** Water quality parameters. Water quality Index. Pre-monsoon. Post-monsoon. Varada River

**INRODUCTION**

 The Varada River basin is a prominent river system in western Karnataka, spanning approximately 386 km in length. The Varada River originates in the Shimoga district of Karnataka, India. The majority of its course flows through the state of Karnataka.

“Relevant studies on the Water Quality Index (WQI) and its modeling have been reviewed. WQI is a valuable and unique rating system that represents the overall water quality status in a single term. It is helpful for selecting appropriate treatment techniques to address specific water quality concerns” (Tyagi et al., 2013). Water quality indices serve as tools for assessing the condition of water bodies.

Developing a WQI generally involves three main steps (US EPA, 2009): Obtaining measurements of individual water quality indicators, converting these measurements into “sub-index” values on a common scale, and Aggregating the sub-index values into an overall WQI score.

Various researchers have proposed different methods to calculate WQI, using five types of aggregation functions: (a) Arithmetic aggregation function, (b) Multiplicative aggregation function, (c) Geometric mean, (d) Harmonic mean, and (e) Minimum operator.

Horton (1965) used “the arithmetic aggregation function in his WQI model. He selected ten commonly measured water quality variables, including dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity, and chloride. The weighted arithmetic mean of these variables, along with temperature and observable pollution, was used to compute the final index. The index weights ranged from 1 to 4”.

Brown et al. (1970) followed a similar approach, “using basic arithmetic weighting without the multiplicative components”. This work was supported by the National Sanitation Foundation (NSF), where water quality variables were selected using the Delphi method (Dalkey, 1968), a structured technique that “synthesizes expert opinion. The NSF WQI applied logarithmic transformations to convert individual variable values into sub-index scores”.

Dinius (1987) developed “an index based on a multiplicative aggregation approach with a decreasing scale, expressing values as a percentage of “perfect” water quality (100 %)”. Earlier work on multiplicative WQIs was carried out by Helmer and Rescher (1959) and Dalkey and Helmer (1963), who introduced modifications to the Delphi method (Dalkey, 1968). Subsequent studies—Brown et al. (1972), Bhargava et al. (1998), Dwivedi et al. (1997), and Landwehr and Deininger (1976)—also adopted multiplicative formulations, assigning parameter weights based on expert judgment and authorial analysis. Dee et al. (1973) proposed “a related framework for evaluating the environmental impacts of large-scale water‐resource projects”.

McClelland (1974) introduced “a weighted geometric mean for WQI aggregation, arguing that the arithmetic mean suffered from “eclipsing” low-value parameters”. Later researchers—including Landwehr and Deininger (1976), Walski and Parker (1974), Bhargava (1983), and Dinius (1987)—also employed the weighted geometric mean to mitigate this issue.

Dojlido et al. (1994) applied “the harmonic mean to compute a WQI without explicit parameter weights”. They found this approach more sensitive to the most impaired indicator—thus reducing eclipsing—while still reflecting the influence of all variables (Walsh & Wheeler, 2012). “Two prominent harmonic‐mean indices are the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) and the British Columbia Water Quality Index. The CCME WQI benchmarks observations against regulatory standards or site‐specific background concentrations rather than rating curves” (CCME, 2001; Khan et al., 2003; Lumb et al., 2006). “The British Columbia index, developed by the Canadian Ministry of Environment in 1995, similarly classifies water quality by comparing measured parameters to predefined limits, facilitating a comprehensive assessment across all monitored variables” (Bharti & Katyal, 2011).

**Location of the Study Area**

The Varada basin covers an area of 1,464 km² and lies between latitudes 14°05'25" to 14°42'25" N and longitudes 74°48'15" to 75°12'25" E (Figure 1). The Varada River, a tributary of the Tungabhadra River, originates at Varadamula near Ikkeri in Sagara Taluk of Shimoga district, and flows in a north and northeast direction before joining the Tungabhadra at Bankasana. The southern and southwestern parts of the basin are situated in the Western Ghats. The region is deeply dissected, heavily forested, and the river is in its youthful stage.





Figure 2 Water sampling stations of Varada river basin

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl.No.** | **Location** | **pH** | **EC** | **TDS** | **Ca2+** | **Mg2+** | **Na+** | **K+** | **CO3-** | **HCO3-** | **SO4-** | **NO3-** | **Cl-** |
| 1 | Bheemankone | 6.6 | 410 | 290 | 75 | 32 | 51 | 10 | 10 | 99 | 110 | 23 | 115 |
| 2 | Ulluluru | 6.6 | 200 | 140 | 47 | 40 | 44 | 9.5 | 10 | 83 | 82 | 22 | 82 |
| 3 | Varadamula | 6.5 | 300 | 210 | 42 | 36 | 43 | 9.2 | 11.5 | 65 | 110 | 15 | 90 |
| 4 | Ikkeri | 7.2 | 390 | 270 | 46 | 32 | 52 | 9.3 | 9.2 | 85 | 93 | 16 | 80 |
| 5 | Talaguppa | 7.2 | 400 | 280 | 65 | 38 | 60 | 8.9 | 11 | 70 | 110 | 11 | 100 |
| 6 | Siddapur | 7.0 | 290 | 200 | 60 | 32 | 62 | 9.6 | 9.6 | 42 | 85 | 12 | 70 |
| 7 | Sagar | 6.7 | 240 | 170 | 42 | 28 | 54 | 8.8 | 8 | 72 | 72 | 17 | 62 |
| 8 | Shirvanthe | 6.5 | 240 | 170 | 44 | 30 | 40 | 10 | 10 | 36 | 96 | 12 | 68 |
| 9 | Aigod | 6.6 | 260 | 180 | 37 | 35 | 42 | 2.5 | 14.2 | 45 | 83 | 15 | 72 |
| 10 | Akkunji | 6.9 | 250 | 175 | 32 | 32 | 42 | 2.6 | 8.5 | 32 | 78 | 16 | 62 |
| 11 | Chandragutti | 7.0 | 220 | 154 | 45 | 28 | 32 | 11 | 10 | 95 | 85 | 12 | 67 |
| 12 | Unchalli | 6.9 | 200 | 140 | 27 | 25 | 22 | 6 | 9 | 21 | 63 | 10 | 53 |
| 13 | Bennur | 7.0 | 220 | 154 | 42 | 37 | 38 | 11.1 | 16.2 | 32 | 83 | 08 | 72 |
| 14 | Arekoppa | 7.2 | 200 | 140 | 35 | 15 | 26 | 4.2 | 8.5 | 28 | 56 | 08 | 52 |
| 15 | Bidarahalli | 7.4 | 220 | 160 | 26 | 12 | 28 | 5.6 | 11 | 29 | 79 | 48 | 42 |
| 16 | Iduru | 6.5 | 210 | 150 | 32 | 14 | 28 | 6.2 | 11 | 85 | 62 | 12 | 52 |
| 17 | Sugavi | 7.5 | 220 | 160 | 28 | 10 | 22 | 1.2 | 12 | 75 | 54 | 10 | 72 |
| 18 | Angadi | 7.4 | 270 | 170 | 42 | 18 | 25 | 6.9 | 6.3 | 43 | 82 | 16 | 82 |
| 19 | Koralkatte | 7.0 | 220 | 154 | 43 | 16 | 25 | 8.3 | 8.2 | 21 | 86 | 18 | 68 |
| 20 | Banavasi | 7.4 | 250 | 175 | 43 | 22 | 32 | 1.9 | 11 | 35 | 76 | 22 | 72 |
| 21 | Kerekoppa | 7.8 | 320 | 220 | 42 | 26 | 35 | 1.2 | 12 | 49 | 94 | 28 | 82 |
| 22 | Tavanandi | 7.7 | 500 | 350 | 62 | 41 | 49 | 6.3 | 12.5 | 110 | 112 | 40 | 105 |
| 23 | Hosabale | 7.8 | 430 | 300 | 48 | 40 | 50 | 5.3 | 17.5 | 95 | 120 | 35 | 92 |
| 24 | Ulavi | 7.7 | 520 | 350 | 68 | 52 | 53 | 6.8 | 21 | 100 | 120 | 29 | 100 |
| 25 | Lingadalli | 7.7 | 520 | 350 | 62 | 22 | 54 | 5.4 | 11 | 100 | 86 | 25 | 100 |
| **Min=** | **6.5** | **200** | **140** | **26** | **10** | **22** | **1.2** | **6.3** | **21** | **54** | **8** | **42** |
| **Max=** | **7.8** | **520** | **350** | **75** | **52** | **62** | **11.1** | **21** | **110** | **120** | **48** | **115** |
| **Avg.=** | **7.1** | **300** | **208.4** | **45.4** | **28.5** | **40.3** | **6.7** | **11.1** | **61.8** | **87.0** | **19.2** | **76.4** |

**Table 1: Pre-monsoon analyzed groundwater samples of Varada River basin**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl.No.** | **Location** | **pH** | **EC** | **TDS** | **Ca2+** | **Mg2+** | **Na+** | **K+** | **CO3** | **HCO3-** | **SO4-** | **NO3-** | **Cl-** |
| 1 | Bheemankone | 6.6 | 400 | 280 | 60 | 30 | 50 | 9.9 | 10 | 90 | 100 | 20 | 100 |
| 2 | Ulluluru | 6.5 | 180 | 130 | 45 | 40 | 40 | 8.2 | 10 | 80 | 80 | 15 | 80 |
| 3 | Varadamula | 6.4 | 290 | 200 | 40 | 35 | 45 | 9.0 | 11 | 60 | 110 | 10 | 90 |
| 4 | Ikkeri | 7.2 | 390 | 280 | 46 | 30 | 51 | 9.1 | 9.2 | 80 | 90 | 15 | 80 |
| 5 | Talaguppa | 7.2 | 410 | 290 | 60 | 35 | 58 | 8.0 | 11 | 70 | 100 | 10 | 100 |
| 6 | Siddapur | 7.0 | 290 | 200 | 55 | 30 | 52 | 9.2 | 13 | 40 | 80 | 10 | 70 |
| 7 | Sagar | 6.7 | 230 | 160 | 40 | 25 | 50 | 8.2 | 7.8 | 70 | 70 | 15 | 60 |
| 8 | Shirvanthe | 6.5 | 240 | 170 | 40 | 25 | 42 | 9.1 | 9.8 | 30 | 95 | 10 | 65 |
| 9 | Aigod | 6.6 | 260 | 180 | 35 | 30 | 41 | 1.2 | 14 | 40 | 80 | 10 | 70 |
| 10 | Akkunji | 6.9 | 240 | 170 | 30 | 30 | 39 | 1.8 | 08 | 30 | 75 | 12 | 60 |
| 11 | Chandragutti | 7.0 | 220 | 150 | 40 | 25 | 32 | 9.9 | 10 | 90 | 70 | 10 | 65 |
| 12 | Unchalli | 6.9 | 200 | 140 | 25 | 20 | 21 | 4.8 | 08 | 20 | 60 | 07 | 50 |
| 13 | Bennur | 7.0 | 210 | 150 | 40 | 35 | 34 | 1.1 | 16 | 30 | 80 | 05 | 70 |
| 14 | Arekoppa | 7.2 | 190 | 130 | 30 | 10 | 21 | 4.0 | 8 | 27 | 50 | 08 | 50 |
| 15 | Bidarahalli | 7.4 | 200 | 140 | 25 | 10 | 26 | 5.0 | 9.9 | 29 | 70 | 10 | 45 |
| 16 | Iduru | 6.5 | 200 | 140 | 30 | 10 | 28 | 6.0 | 10 | 81 | 60 | 10 | 50 |
| 17 | Sugavi | 7.5 | 210 | 150 | 25 | 08 | 20 | 1.0 | 10 | 70 | 50 | 05 | 70 |
| 18 | Angadi | 7.4 | 260 | 180 | 40 | 15 | 21 | 6.8 | 6 | 40 | 80 | 15 | 80 |
| 19 | Koralkatte | 7.0 | 210 | 150 | 40 | 15 | 24 | 8.1 | 8 | 21 | 80 | 10 | 65 |
| 20 | Banavasi | 7.4 | 240 | 170 | 42 | 20 | 29 | 1.8 | 10 | 34 | 75 | 20 | 70 |
| 21 | Kerekoppa | 7.8 | 300 | 210 | 40 | 25 | 30 | 1.0 | 10 | 45 | 90 | 25 | 80 |
| 22 | Tavanandi | 7.7 | 500 | 360 | 60 | 40 | 49 | 6.2 | 12 | 100 | 110 | 25 | 105 |
| 23 | Hosabale | 7.8 | 420 | 333 | 45 | 45 | 48 | 5.2 | 16 | 92 | 100 | 30 | 90 |
| 24 | Ulavi | 7.7 | 500 | 350 | 65 | 50 | 50 | 6.8 | 20 | 99 | 115 | 25 | 100 |
| 25 | Lingadalli | 7.7 | 510 | 360 | 60 | 20 | 52 | 5.3 | 10 | 96 | 80 | 20 | 100 |
| **Min=** | **6.4** | **180** | **130** | **25** | **8** | **20** | **1** | **6** | **20** | **50** | **5** | **45** |
| **Max=** | **7.8** | **510** | **360** | **65** | **50** | **58** | **9.9** | **20** | **100** | **115** | **30** | **105** |
| **Avg.=** | **7.1** | **292** | **206.9** | **42.3** | **26.3** | **38.1** | **5.8** | **10.7** | **58.5** | **82** | **14.0** | **74.6** |

**Table 2: Post-monsoon analyzed groundwater samples of Varada River basin**

**RESEARCH METHODOLOGY**

WQI is a widely used equation to assess groundwater quality for drinking purposes (Subba Rao, 1997), (Mouna *et al.,* 2012, Pradhan *et al.,* 2001, Channamma and Arunkumar 2024). It is determined using the relative weight method, consisting of three steps: weight assigning, where each criteria is assigned a weight based on its significance, and calculation of relative weight using an equation (Brown *et al.,* 1970).

Wi= $\frac{Wi}{\sum\_{i=0}^{n}wi}$

“Rating of quality (qi)” contains the third step, as determined by the next equation:

Qi = $(\frac{Ci}{Si}) ×100$

Where, the concentration of each parameter is denoted as Ci in individual water sample, and Si is the specified value of an individual parameter prescribed by WHO. Lastly, the Wi and qi were used to determine the SIi for each parameters and therefore WQI can be determined by the equation as shown below:

SIi = Wi × qi

WQI = $\sum\_{i=0}^{n}SIi$

Where, SIi is the sub-index of each parameter.

|  |  |  |
| --- | --- | --- |
| **Class** | **WQI values** | **WQI Results** |
| 1 | <50 | Excellent |
| 02 | 51-100 | Good |
| 03 | 101-200 | Poor |
| 04 | 201-300 | Very poor |
| 05 | >300 | Unsuitable |

**Table 3: Classification of drinking WQI (Muralidhara Reddy *et al.,* 2019)**

**Result and Discussion**

|  |
| --- |
| **Table 4: Scale of WQI results of Varada River Basin for pre and post-monsoon seasons** |
|  | **Pre-monsoon** | **Post-monsoon** |
| **Sl.No.** | **Location** | WQI results | Category | WQI results | Category |
| 1 | Bheemankone | 53.80 | Good | 52.78 | Good |
| 2 | Ulluluru | 51.63 | Good | 48.91 | Excellent |
| 3 | Varadamula | 50.10 | Good | 49.64 | Excellent |
| 4 | Ikkeri | 55.04 | Good | 54.38 | Good |
| 5 | Talaguppa | 57.59 | Good | 55.99 | Good |
| 6 | Siddapur | 56.76 | Good | 53.58 | Good |
| 7 | Sagar | 52.38 | Good | 50.48 | Excellent |
| 8 | Shirvanthe | 48.96 | Excellent | 48.10 | Excellent |
| 9 | Aigod | 45.27 | Excellent | 43.27 | Excellent |
| 10 | Akkunji | 46.16 | Excellent | 44.37 | Excellent |
| 11 | Chandragutti | 49.49 | Excellent | 48.17 | Excellent |
| 12 | Unchalli | 42.24 | Excellent | 40.41 | Excellent |
| 13 | Bennur | 51.76 | Good | 43.43 | Excellent |
| 14 | Arekoppa | 42.15 | Excellent | 40.09 | Excellent |
| 15 | Bidarahalli | 45.98 | Excellent | 42.92 | Excellent |
| 16 | Iduru | 41.25 | Excellent | 40.51 | Excellent |
| 17 | Sugavi | 39.82 | Excellent | 38.63 | Excellent |
| 18 | Angadi | 45.65 | Excellent | 44.15 | Excellent |
| 19 | Koralkatte | 44.78 | Excellent | 43.80 | Excellent |
| 20 | Banavasi | 44.63 | Excellent | 43.46 | Excellent |
| 21 | Kerekoppa | 47.42 | Excellent | 45.71 | Excellent |
| 22 | Tavanandi | 56.99 | Good | 56.03 | Good |
| 23 | Hosabale | 56.25 | Good | 55.88 | Good |
| 24 | Ulavi | 59.14 | Good | 57.89 | Good |
| 25 | Lingadalli | 54.72 | Good | 53.62 | Good |

**The water quality indices obtained for the three stations are shown in Table 4 and graphically in Figure. 3. (Table 4) shows the scale of water quality based on WQI.**



**Figure 3: WQI in Varada River basin for pre and post-monsoon season**

**Water quality of Varada River Basin**

In the present study, the **pH** ranged from 6.5 to 7.8 with an average of 7.1 (Table 1) and 6.4 to 7.8 with an average of 7.1(Table 2) for both two seasons.



**Figure 4: Special variation of pH at Varada river basin for pre and post-monsoon season**

**EC** is a measure of TDS in water. In this study, EC values are 200 to 500 m.mho/cm average value was 300 m.mho/cm (Table 1) and 180 to 510 m.mho/m and average value was 292 m.mho/cm (Table 2). This may be due to the land cover pattern here i.e., semi-green area and forest area thereby less soil erosion of the top soil (Avvanavar and Shrihari 2008). Electrical conductance is the most convenient way of measuring water salinity. EC is determined as the reciprocal of the specific resistance (ohm's/cm) of the water sample at 25°C. Accordingly, the groundwater samples of the Varada river basin are classified (Table 1 and 2) and spatial variation in Varada river basin is given in Figure 5.



**Figure 5: Special variation of EC at Varada river basin for pre and post-monsoon season**

**Total dissolved solids (TDS**). The amount of TDS in groundwater samples differs in different type of geographical structures and their mineral solubility (WHO, 1984). In the groundwater samples, the TDS value in pre-monsoon season varies between 140 to 350 ppm/L, average value is 208.4 ppm/L (Table 1) and 130 to 360 ppm/L, average value is 206.9 ppm/L (Table 2) in post-monsoon season. WHO (2011) recommended that the maximum allowable TDS is 500 ppm/L and the maximum is 350 ppm/L and 360 ppm/L, so most samples fall within the allowable limit.

**Bicarbonate (HCO3−)** in groundwater ranges from 21 ppm/L to 110 ppm/L, with a mean value of 61.8 ppm/L (Table 1) and 20 ppm/L to 100 ppm/L with an average value of 58.5 ppm/L (Table 2). The HCO3− concentration in groundwater is comparatively higher, it doesn’t harm human health. In the study area maximum number of groundwater samples is fall down within the permissible limit (WHO, 2011).

**Chloride** concentration in the study region ranges from 42 ppm/L to 115 ppm/L, with a mean value of 76.4 ppm/L (Table 1) and 45 ppm/L to 105 ppm/L with an average value of 74.6 ppm/L (Taable 2) for both two seasons (Table 2). The acceptable limit for chloride in drinking water is 250 mg/L, and the permissible limit is 1000 mg/L (WHO 2011). In the study area, all groundwater samples were fall under the recommended limit.

**Calcium (Ca2+) and magnesium (Mg2+).** The concentration of calcium in pre-monsoon season ranges between 26 ppm/L to 75 ppm/L, with a mean value of 45.4 ppm/L (Table 1) and 25 ppm/L to 65 ppm/L with an average value of 42.3 ppm/L (Table 2) in post-monsoon season. The value of magnesium ranges between 10 ppm/L to 52 ppm/L, with a mean value of 28.5 ppm/L (Table 1) and 8 ppm/L to 50 ppm/L with an average value of 26.3 ppm/L (Table 2). According to WHO 1984, the permissible limit of calcium is 200 mg/L.

**Sodium (Na+) and potassium (K+)** ions, are available in rock and soil, and easily dissolved in groundwater: generally, these ions are not dangerous. Nevertheless, if it crosses the permissible limit, it may be harmful to human health, like hypertension, heart illness, or kidney problems. Sodium ranges between 22 ppm/L and 62 ppm/L, with an average value of 40.3 ppm/L (Table 1) and 20 ppm/L to 58 ppm/L with an average value of 38.1 ppm/L (Table 2) for both two seasons. Potassium varies between 1.2 ppm/L and 11.2 ppm/L, with a mean value of 6.7 ppm/L (Table 1), and 1 ppm/L to 9.9 ppm/L with an average value of 5.8 ppm/L (Table 2). Hence all samples falls under within the permissible limit according to BIS 2012 standards.

**Sulphate** concentration in the study region ranges between 54 ppm/L to 120 ppm/L and the mean value of 87.0 ppm/L (Table 1) and 50 ppm/L to 115 ppm/L with an average value is 82 ppm/L (Table 2) for both two seasons. All water samples were comes under the permissible limit of sulphate in the study area.

**Nitrate** levels in the study area are found to be 8 ppm/L to 48 ppm/L, with an average value was 19.2 ppm/L (Table 1) and 5 ppm/L to 30 ppm/L with an average value is 14.0 ppm/L (Table 2) for both two seasons. There is no significant increase in the Nitrate levels at these stations in the monsoon period. According to BIS standards permissible limit is 45 mg/L. This suggests that the natural occurring sources may be the cause of low Nitrate levels in these study areas.

**Conclusion**

In the present study, all the water quality samples showed only minor variations and were found to fall within the permissible limits in the Varada River basin. A slight variation in pH was observed across all sampling sites. Nitrate levels remained within the permissible limits during both seasons. The Water Quality Index (WQI) results indicated that, during the pre-monsoon season, 12 water samples fell under the **“Good”** category, while the remaining 13 samples were classified as **“Excellent.”** In the post-monsoon season, 8 water samples were categorized as **“Good** and the remaining 17 samples as “Excellent” (Table 4). There is a need for regular and comprehensive monitoring of water quality in the Varada River basin, which is currently being undertaken by the State Pollution Control Board. Ongoing monitoring is essential to identify changes or trends in water quality over time and space, to gather the necessary data for designing effective pollution prevention programs, and to assess whether objectives such as compliance with pollution control regulations and implementation of effective management strategies are being achieved.

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