***Original Research Article***

**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 well-known river in western Karnataka and is approximately 386 km in length. The Varada River starts its journey of Shimoga district in the state of Karnataka, India. The majority course of the river flows in the state of Karnataka, India. Relevant studies on water quality index (WQI) and its modeling were reviewed. WQI is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues (Tyagi *et al.,* 2013).Water quality indices are tools to determine conditions of water quality. Creating the WQI involves three main steps (US EPA 2009): (1) obtain measurements on individual water quality indicators (2) transform measurements into ‘‘sub index’’ values to represent them on a common scale (3) aggregate the individual sub index values into an overall WQI value. Various researchers have attempted to develop water quality index based on five types of WQI aggregation functions: Arithmetic aggregation function, (b) multiplicative aggregation function, (b) geometric mean, (c) harmonic mean, and (d) minimum operator. Horton 1965 used the arithmetic aggregation function for the WQI. He selected 10 most commonly measured water quality variables for his index including dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity, and chloride. The arithmetic weighing of the water quality variables was multiplied with the temperature and ‘‘obvious pollution’’ to obtain the sum aggregation function from which the overall water quality index was found out. The index weight ranged from 1 to 4. Similar to Horton (1965), Brown et al. (1970) also employed basic arithmetic weighting, although without the multiplicative variables. This effort was supported by the National Sanitation Foundation (NSF) in which the water quality variables were chosen using the Delphi method (Dalkey 1968), which generates results from the convergence of expert’s opinions. The NSF WQI used logarithmic transforms to convert water quality variable results into sub index values.

Dinius (1987), developed a index based on multiplicative aggregation having decreasing scale, with values expressed as a percentage of perfect water quality corresponding to 100 %. Similar work was carried out by Helmer and Rescher 1959, Dalkey and Helmer 1963 by introducing changes to Delphi method (Dalkey 1968). Brown *et al.* (1972), Bhargava et al. (1998), Dwivedi *et al.* (1997), Landwehr and Deininger (1976) gave multiplicative form of the index where weights to individual parameters were assigned based on a subjective opinion based on the judgment and critical analysis of the author. Dee *et al.* (1973) proposed a system for evaluating the environmental impact of large scale water resources projects.

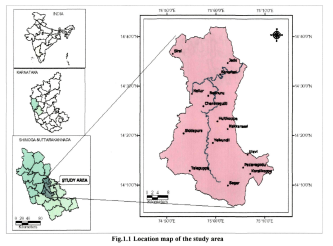
McClelland (1974) introduced the geometric mean form of weighting to the WQI. McClelland was concerned that the arithmetic mean lacked sensitivity to low value parameters, a characteristic later deemed ‘‘eclipsing.’’ McClelland instead proposed the weighted geometric mean. Later researchers (Landwehr and Deininger 1976; Walski and Parker 1974; Bhargava 1983; Dinius 1987) have also employed a weighted geometric mean for aggregation.

Dojlido *et al.,* 1994 used the harmonic mean to find the WQI. This mean does not use weights for the individual indicators. Dojlido *et al.,* (1994) found that it was more sensitive to the most impaired indicator than the arithmetic or harmonic means, reducing eclipsing, while still accounting for the influence of other indicators (Walsh and Wheeler 2012). Other indices based on harmonic means are Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) and British Columbia water quality index. The CCMEWQI compares observations to a benchmark instead of normalizing observed values to subjective rating curves, where the benchmark may be a water quality standard or site specific background concentration (CCME 2001; Khan *et al.,* 2003; Lumb *et al.,* 2006). British Columbia water quality index was developed by the Canadian Ministry of Environment in 1995 as increasing index to evaluate water quality. This index is similar to CCMEWQI where water quality parameters are measured and their violation is determined by comparison with a predefined limit. It provides possibility to make a classification on the basis of all existing measurement parameters (Bharti and Katyal 2011).

**Location of the Study Area**

The Varada basin covers an area of 1464 km2 and it is encompassed within latitudes 14° 05' 25" to 14° 42' 25" N and Latitude 74° 48' 15" to 75° 12' 25" E (Figure 1). The Varada is one of the tributary of River Tungabhadra, takes its origin in Varadamula near Ikkeri of sagara taluk of Shimoga district, flowing towards north and northeast direction before confluence with Tungabhadra at Bankasana. The south and south western part of the basin rests upon the Western Ghats. The area is deeply dissected, heavily forested and the river is extreme youth stage.

Fig 1 : Location map of study area.



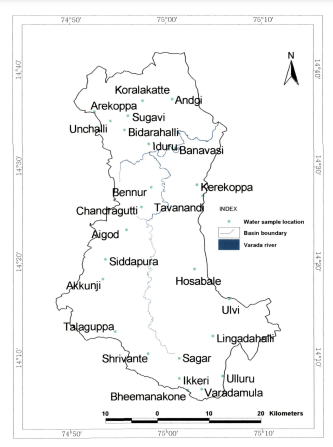


Figure 2 Water sampling stations of Varada river basin

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **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: Shows 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: Shows 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=

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

Qi =

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 =

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: Shows classification of drinking WQI (Muralidhara Reddy *et al.,* 2019)**

**Result and Discussion**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 4: Shows 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 |

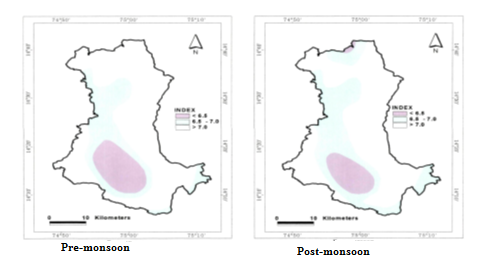
**The water quality indices obtained for the three stations are shown in Table 4 and graphically in Figure. 3. (Table 4) shows the scale of water quality based on WQI.**



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

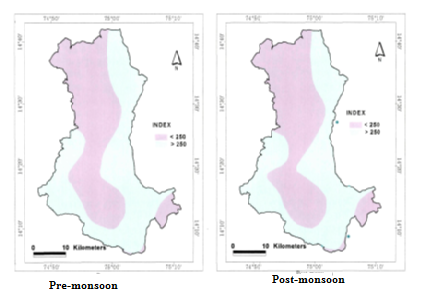
**Water quality of Varada River Basin**

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: Shows 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: Shows 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 parameters showed small variation at the twenty five sampling sites along the Varada River basin. A slight variation of pH was observed for all the sampling sites. Nitrate were found to be within the permissible limit for both different two seasons. The water quality index results revealed that 12 water samples has comes under **“Good”** category and remaining 13 sampling sites has comes under **“Excellent”** category at Varada River basin in pre-monsoon season, and in post-monsoon season 08 water samples has comes under **“Good”** category and remaining 17 sampling sites has **“Excellent”** category at Varada River basin (Table 4). There is a need of regular and detailed water quality monitoring of the Varada River basin which is presently carried out by the state pollution control board. There is a need to the identify changes or trends in water quality over time and space, to obtain necessary information to design specific pollution prevention programs and to determine whether goals such as compliance with pollution regulations or implementation of effective pollution control actions are being met.

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