ASSESSMENT OF WATER QUALITY OF THE BHIMA RIVER FOR DRINKING PURPOSE BY WATER QUALITY INDEX

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ABSTRACT

The objective of this study is to determine various water characteristics of the Bhima River and its suitability for drinking, followed by a water quality index evaluation. For continuous monitoring, samples were taken at eight locations between October 2020 and September 2021. The physicochemical parameters, such as pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), total alkalinity (TA), total hardness (TH), chloride (Cl\(^-\)), sulphate (SO\(_4^{2-}\)), phosphate (PO\(_4^{3-}\)), and nitrate (NO\(_3^-\)) were measured. The measured values of these parameters were compared with Indian standards. Due to anthropogenic activities, values of parameters EC, TH, and TA at all the stations exceeded their BIS limits (The Bureau of Indian Standards). It was found that the river's total water quality index ranged from 45.23 to 75.43, indicating that the water quality varies from good to very poor. Correlation reveals that EC and TDS show remarkable similarities and a strong correlation was existed between total hardness and total alkalinity indicating anthropogenic activities. Therefore, it is important to assess physiochemical concentration of the river water before using it for drinking.

Keywords: Bhima River, correlation, physicochemical parameters, water quality index

INTRODUCTION

Water is the most abundant chemical in the human body. All biological activities occur in water, and it is an active participant in those reactions [1]. Without water, life cannot exist [1, 2]. Rivers serve as the primary supply of drinking water in both urban and rural areas, and they play a vital role in public health and environmental standards [3]. Water in a river is often gathered from rainfall, surface runoff, and the discharge of stored water in natural reservoirs such as a glacier. Rivers, in addition to being a rich source of fish, also indirectly benefit agriculture by providing water for irrigation [4]. Due to rapid increase in human population and industrialization, as well as wastewater disposal, water quality has deteriorated in recent years [5]. The rivers are one of the world’s most contaminated landscapes. Because rivers pass through towns, industrial zones, and agricultural areas, they have long been used for disposal of sewage [6]. According to a World Health Organization (WHO) study, household waste accounts for 80 % of water contamination [7].
Water must be tested before it is used for drinking, residential, agricultural, or industrial reasons. It must be tested using various physicochemical parameters. Evaluation of parameters is necessary for the assessment of water quality and for the comparison of their values to reference standards [8]. Various indices have been developed for quick and concise summarisation of data of several parameters. In 1965, Horton [9] developed the water quality index (WQI) as a statistical technique for combining the results of many parameters to obtain a single score. Generalized WQI, which Brown [10] later developed in 1970, has now undergone fundamental changes and is now more suitable for different purposes [11]. The WQI is a more advanced environmental criterion that is the most active way to describe water quality for drinking purposes [12]. WQI is a value that shows the combined influence of many parameters [13]. Water quality can be observed using physical, chemical, and biological variables. These factors are harmful to human health if their values are higher than the set limits [14].

Many authors, such as Patni et al., [7], Lrk et al., [11], and Gupta et al., [15] have reported on the concentration of physiochemical parameters of river water from different places around the world, as well as the pollution status, using the WQI approach. In many areas, there is a serious water deficit and there are problems with the quality of drinking water. In semi-arid areas, such as Kalaburagi, Karnataka, where rainfall is erratic in both location and timing, it is important to assess the quality of the available water. This is why this area is interested in water quality monitoring. The objective of this study is to use physicochemical standards to assess the water quality status of the Bhima River.

**MATERIALS AND METHODS**

**Study area**

The Bhima River flows through the Karnataka district of Kalaburagi (Figure 1), which is located in the northern part of the state (76° 04" to 77° 42" longitude and 16° 12" to 17° 46" latitude) and is 454 m above mean sea level (MSL). The river is a major tributary of the Krishna River. The study area encompasses eight locations along the river bank. Table 1 shows the sampling locations together with their Global Positioning System (GPS) coordinates, and Figure 1 shows a map with indicated sampling locations.

![Figure 1. Map of Kalaburagi district showing eight sampling locations](image)

**Methodology**

**Sample collection**

Water samples were collected at eight different river locations. For this investigation, ten physicochemical characteristics were determined: pH, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA), total hardness
(TH), chloride (Cl\textsuperscript{-}), phosphate (PO\textsubscript{4}\textsuperscript{3-}), nitrate (NO\textsubscript{3}\textsuperscript{-}), sulphate (SO\textsubscript{4}\textsuperscript{2-}), and dissolved oxygen (DO). On site, pH, EC, and TDS were measured with a digital pen-type meter. The titration technique was used to determine total alkalinity, total hardness, and chloride. Fixatives were added on site to measure dissolved oxygen, which was then examined using Winkler's technique. All parameters were examined using standardized procedures recommended by Trivedy and Goel [16] and the American Public Health Association (APHA) [17].

Water quality index

The water quality index (WQI) was computed by applying the weighted arithmetic index approach. This equation was used to determine the quality rating scale for each parameter. The WQI was determined using drinking water quality criteria specified by the Bureau of Indian Standards (BIS) [18].

Calculation of water quality index

Unit weight factor for each parameter is calculated by the following equation:

\[ W_n = K/S_n \]  \hspace{1cm} (1)

where \( W_n \) is the unit weight of each parameter, \( n \) represents a number of parameters, \( S_n \) indicates the standard permissible limit of the \( n^{th} \) parameter, and \( K \) is the proportionality constant.

Sub-index \((Q_n)\) is calculated by the following equation:

\[ Q_n = [(V_n - V_i) / (V_s - V_i)] \cdot 100 \]  \hspace{1cm} (2)

where \( V_n \) is the obtained concentration of the \( i^{th} \) determinant, \( V_i \) is the ideal value of the \( i^{th} \) determinant in fresh water, and \( V_s \) is the standard value of the \( i^{th} \) determinant.

Except for pH and DO, where \( V_i = 7 \) and 14.6 respectively, zero is the optimal value for all determinants.

Combining equation 1 and 2, WQI is shown as follows:

\[ WQI = W_n \cdot Q_n \]  \hspace{1cm} (3)

RESULTS AND DISCUSSION

Details of the physicochemical properties for specific study sites are listed in Table 1. The obtained results were compared with the standard specified by the Bureau of Indian Standards (BIS) as shown in Table 2. According to the BIS [18], the pH range is 6.5 to 8.5. The human body stops making vitamins and minerals when the pH drops below 6.4. Water tastes sourer when the pH exceeds 8.5, while above 11 it causes eye discomfort and skin problems. It is safe to consume water with a pH of 5.5 - 6. pH values in the range of 3.5 to 4.5 affect aquatic life [19 - 21]. The pH in this study ranges from 7.6 to 8.1, with an average value of 7.87, which is below the permissible limit of 8.5.

Electrical conductivity is the ability of water to conduct electric current. The majority of salts in water are in the ionic form [22]. Mean EC was 848.76 µS/cm, varying from 789.6 to 883 µS/cm. This shows that the EC of all the samples has exceeded the values of 300 µS/cm according to BIS. Total dissolved solids can be assessed indirectly by calculating EC. A higher concentration of salts in water conducts more electricity.

High TDS levels have a negative impact on public health by damaging the central nervous system and causes facial paralysis including tongue and lips [19, 23 - 25]. In this research, the obtained TDS values were in the range of 414.6 to 457.6 mg/l and a mean value was 453.08 mg/l. This means that the obtained TDS values are significantly below the BIS [18] permissible limit of 500 mg/l.

Chloride is one of the most common anions on the planet. The amount of chloride in the environment rises as a result of industrial waste, agricultural runoff and animal excretion. Water with high chloride content has a salty flavour. Chloride levels that
The high concentration of phosphate in industrial, agricultural, and sewage waste causes contamination of the aquatic body, which encourages the proliferation of microorganisms. Muscle damage, respiratory problems, and renal failure are symptoms of a high phosphate levels [35]. Eutrophication and dissolved oxygen depletion are caused by an increased concentrations of phosphorus in reservoirs and lakes [25, 36]. The obtained values of phosphate were within the permissible limit of 5 mg/l, and ranged from 1.33 to 3.17 mg/l with a mean value of 2.27 mg/l.

The concentration of nitrate in natural water is increasing as a result of various agricultural activities [37]. Increased nitrate levels in surface water cause a variety of problems, including reduced oxygen levels in the water, which affects aquatic flora and fauna [15]. A blue baby syndrome occurs in the human body as a result of the reaction of iron and nitrate in red blood cells, whereby methaemoglobin is formed, which prevents the increase in oxygen levels. Infants under one year of age are exposed to a high risk of developing methemoglobinemia due to consumption of water containing high levels of nitrates [21, 35]. The values of nitrates in this study ranged from 1.11 to 1.58 mg/l, and the mean value was 1.4 mg/l. These values are considerably below the permissible limit of 45 mg/l.

Sulphate is another significant chemical parameter, it is a natural substance and is abundant in the environment. It is largely obtained from weathering of rocks and anthropogenic activities [38]. Water with high sulphate levels can have a harsh flavour and a laxative effect resulting in diarrhea and dehydration [39]. Infants are particularly sensitive to its effect [40]. The permissible limit of sulphate is 150 mg/l. The concentration of sulphate in the examined samples was significantly below the permissible limit of 150 mg/l. Measured values ranged from 54.33 to 78.33, and the mean value was 70.27 mg/l.
Table 1. Water quality parameters of the Bhima River, expressed as mean values

<table>
<thead>
<tr>
<th>Site code</th>
<th>Site name</th>
<th>Coordinates</th>
<th>pH</th>
<th>EC (µS/cm)</th>
<th>TDS (mg/l)</th>
<th>DO (mg/l)</th>
<th>TA (mg/l)</th>
<th>TH (mg/l)</th>
<th>Cl⁻ (mg/l)</th>
<th>PO₄³⁻ (mg/l)</th>
<th>SO₄²⁻ (mg/l)</th>
<th>NO₃⁻ (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Gangapur</td>
<td>17° 10' 06'' N 76° 30' 57'' E</td>
<td>7.7</td>
<td>875</td>
<td>418.6</td>
<td>8.24</td>
<td>301.73</td>
<td>342.78</td>
<td>165.33</td>
<td>1.74</td>
<td>67</td>
<td>1.38</td>
</tr>
<tr>
<td>S2</td>
<td>Sagnur</td>
<td>17° 05' 57'' N 76° 32' 34'' E</td>
<td>7.6</td>
<td>860</td>
<td>414.6</td>
<td>8.99</td>
<td>270.2</td>
<td>310.06</td>
<td>160.02</td>
<td>1.33</td>
<td>63</td>
<td>1.21</td>
</tr>
<tr>
<td>S3</td>
<td>Chinamalla</td>
<td>17° 04' 53'' N 76° 34' 57'' E</td>
<td>7.6</td>
<td>805.6</td>
<td>457.6</td>
<td>9.33</td>
<td>300.6</td>
<td>332.16</td>
<td>159.22</td>
<td>1.53</td>
<td>54.33</td>
<td>1.11</td>
</tr>
<tr>
<td>S4</td>
<td>Nelogi</td>
<td>17° 03' 45'' N 76° 34' 02'' E</td>
<td>7.9</td>
<td>861.3</td>
<td>444</td>
<td>7.74</td>
<td>309.03</td>
<td>346.63</td>
<td>183.3</td>
<td>2.51</td>
<td>77.33</td>
<td>1.52</td>
</tr>
<tr>
<td>S5</td>
<td>Harwal</td>
<td>17° 03' 39'' N 76° 41' 12'' E</td>
<td>8.1</td>
<td>883</td>
<td>439.3</td>
<td>6.44</td>
<td>313.46</td>
<td>347.2</td>
<td>186.47</td>
<td>3.17</td>
<td>78.33</td>
<td>1.52</td>
</tr>
<tr>
<td>S6</td>
<td>Rasangi</td>
<td>17° 04' 51'' N 76° 42' 15'' E</td>
<td>7.9</td>
<td>871.3</td>
<td>457.3</td>
<td>8.21</td>
<td>275.76</td>
<td>313.3</td>
<td>170.41</td>
<td>2.27</td>
<td>71</td>
<td>1.3</td>
</tr>
<tr>
<td>S7</td>
<td>Saradgi-B</td>
<td>17° 09' 02'' N 76° 46' 39'' E</td>
<td>8.1</td>
<td>789.6</td>
<td>456.3</td>
<td>6.32</td>
<td>294.66</td>
<td>339.4</td>
<td>187.86</td>
<td>3.15</td>
<td>74</td>
<td>1.56</td>
</tr>
<tr>
<td>S8</td>
<td>Jevargi</td>
<td>17° 02' 34'' N 76° 48' 50'' E</td>
<td>8.1</td>
<td>844.3</td>
<td>447</td>
<td>7.76</td>
<td>317.1</td>
<td>346.63</td>
<td>187.1</td>
<td>2.46</td>
<td>77.2</td>
<td>1.58</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>7.87</td>
<td>848.76</td>
<td>453.08</td>
<td>7.87</td>
<td>297.81</td>
<td>334.77</td>
<td>174.96</td>
<td>2.27</td>
<td>70.27</td>
<td>1.4</td>
</tr>
<tr>
<td>BIS</td>
<td></td>
<td></td>
<td>8.5</td>
<td>300</td>
<td>500</td>
<td>5</td>
<td>120</td>
<td>300</td>
<td>250</td>
<td>5</td>
<td>150</td>
<td>45</td>
</tr>
</tbody>
</table>

EC - Electrical conductivity, TDS - Total dissolved solids, DO - Dissolved oxygen, TA - Total alkalinity, TH - Total hardness, Cl⁻ - Chloride, SO₄²⁻ - Sulphate, PO₄³⁻ - Phosphate, NO₃⁻ - Nitrate

Table 2. Drinking water standards according to BIS 2012

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Parameters, unit</th>
<th>BIS Standards</th>
<th>Relative weight (Wi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>8.5</td>
<td>0.207294</td>
</tr>
<tr>
<td>2</td>
<td>EC, µS/cm</td>
<td>300</td>
<td>0.005873</td>
</tr>
<tr>
<td>3</td>
<td>TDS, mg/l</td>
<td>500</td>
<td>0.003524</td>
</tr>
<tr>
<td>4</td>
<td>DO, mg/l</td>
<td>5</td>
<td>0.352401</td>
</tr>
<tr>
<td>5</td>
<td>TA, mg/l</td>
<td>120</td>
<td>0.014683</td>
</tr>
<tr>
<td>6</td>
<td>TH, mg/l</td>
<td>300</td>
<td>0.005873</td>
</tr>
<tr>
<td>7</td>
<td>Cl⁻, mg/l</td>
<td>250</td>
<td>0.007048</td>
</tr>
<tr>
<td>8</td>
<td>PO₄³⁻, mg/l</td>
<td>5</td>
<td>0.352401</td>
</tr>
<tr>
<td>9</td>
<td>SO₄²⁻, mg/l</td>
<td>150</td>
<td>0.011747</td>
</tr>
<tr>
<td>10</td>
<td>NO₃⁻, mg/l</td>
<td>45</td>
<td>0.039156</td>
</tr>
</tbody>
</table>

ΣWi = 1.00

Water quality index

The WQI enables a broad investigation of water quality at different levels that affect a river’s ability to support life and determines whether the general condition of water bodies poses a possible risk for different water uses [21].

The results in Table 3 show that the water quality from all eight sampling sites is within the range of good to very poor (26 < WQI < 100), making it suitable for irrigation and industry. According to Table 4, out of the eight locations, the water quality was good at S2 and S3, poor at S1, S4, S6, and S8, and very poor at S5 and S7. The geographic location of the research area, which was characterized by anthropogenic activities, agricultural runoff, the use of lead batteries, and bridge construction activities, may be the cause of water quality degradation.

Table 3. WQI ranges, status and possible use of the water

<table>
<thead>
<tr>
<th>WQI range</th>
<th>Water quality status (WQS)</th>
<th>Possible use</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 25</td>
<td>Excellent water quality</td>
<td>Drinking, irrigation and industrial purposes</td>
</tr>
<tr>
<td>26 - 50</td>
<td>Good water quality</td>
<td>Drinking, irrigation and industrial purposes</td>
</tr>
<tr>
<td>51 - 75</td>
<td>Poor water quality</td>
<td>Irrigation and industrial purposes</td>
</tr>
<tr>
<td>76 - 100</td>
<td>Very poor water quality</td>
<td>Irrigation</td>
</tr>
<tr>
<td>Above 100</td>
<td>Not suitable for drinking</td>
<td>Appropriate treatment is required before use</td>
</tr>
</tbody>
</table>
Table 4. WQI values of samples

<table>
<thead>
<tr>
<th>Sites</th>
<th>WQI</th>
<th>Water quality status</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>52.76</td>
<td>Poor</td>
</tr>
<tr>
<td>S2</td>
<td>45.63</td>
<td>Good</td>
</tr>
<tr>
<td>S3</td>
<td>45.81</td>
<td>Good</td>
</tr>
<tr>
<td>S4</td>
<td>66.68</td>
<td>Poor</td>
</tr>
<tr>
<td>S5</td>
<td>75.31</td>
<td>Very poor</td>
</tr>
<tr>
<td>S6</td>
<td>60.23</td>
<td>Poor</td>
</tr>
<tr>
<td>S7</td>
<td>75.43</td>
<td>Very poor</td>
</tr>
<tr>
<td>S8</td>
<td>68.33</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Correlation

A correlation analysis is a statistical technique that shows the relationship between two variables. When the correlation coefficient is closer to +1 or -1, a linear relationship between the variables x and y is more likely to occur [25]. Correlation was performed in Microsoft Excel. The physicochemical connections between the different parameters represented in Table 5 show strong correlation (> 0.7 - 0.9), moderate (> 0.5 - 0.7), and weak correlation (> 0.3 - 0.5). Strong correlations exist between pH and phosphate, nitrate, sulphate, and chloride. Electrical conductivity and TDS show a significant correlation. Strong correlations exist between total hardness and total alkalinity. Positive correlations exist between chloride, nitrate, phosphate, and sulphate. The few correlation parameters that are still present are moderately to negatively correlated. Agricultural runoff is the main source of nitrates, phosphates, sulphates, and chlorides. Total hardness and total alkalinity are possible outcomes of human activity.

Table 5. Correlation matrix of physicochemical parameters of Bhima River

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC</th>
<th>TDS</th>
<th>DO</th>
<th>TA</th>
<th>TH</th>
<th>Cl1</th>
<th>SO42-</th>
<th>PO43-</th>
<th>NO3-</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>-0.72</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>-0.37</td>
<td>0.71</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>-0.88</td>
<td><strong>0.66</strong></td>
<td>*<strong>0.38</strong></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TA</td>
<td>0.50</td>
<td>-0.54</td>
<td>-0.71</td>
<td>-0.42</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TH</td>
<td>0.53</td>
<td>-0.64</td>
<td>-0.76</td>
<td>-0.55</td>
<td><strong>0.95</strong></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl1</td>
<td>0.96</td>
<td>-0.70</td>
<td>-0.39</td>
<td>-0.88</td>
<td><strong>0.60</strong></td>
<td><strong>0.66</strong></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO42-</td>
<td>0.94</td>
<td>-0.73</td>
<td>-0.41</td>
<td>-0.95</td>
<td>*<strong>0.47</strong></td>
<td><strong>0.56</strong></td>
<td>0.93</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PO43-</td>
<td>0.88</td>
<td>-0.53</td>
<td>-0.37</td>
<td>-0.81</td>
<td>*<strong>0.45</strong></td>
<td><strong>0.52</strong></td>
<td>0.91</td>
<td>0.82</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>NO3-</td>
<td>0.88</td>
<td>-0.68</td>
<td>-0.47</td>
<td>-0.85</td>
<td><strong>0.60</strong></td>
<td>0.70</td>
<td>0.94</td>
<td>0.83</td>
<td>0.93</td>
<td>1</td>
</tr>
</tbody>
</table>

* Strong correlation (> 0.9 - 0.7), ** Moderate correlation (0.5 - 0.7), *** Weak correlation (0.3 - 0.5),
EC - Electrical conductivity, TDS - Total dissolved solids, DO - Dissolved oxygen, TA - Total alkalinity, TH - Total hardness, Cl - Chloride, SO42- - Sulphate, PO43- - Phosphate, NO3- - Nitrate

CONCLUSION

In order to assess the physicochemical characteristics of the water from the Bhima River, eight different sample locations along the length of the river were carefully selected. The total amount of water pollution in the river was calculated using the WQI. The average river water quality index (WQI) was found to be 61.27, which means that overall quality of the river water is poor and unsafe for drinking. The water quality index for the Bhima River ranges from 45.63 to 75.43 depending on the sampling location, indicating that it is good to very poor for drinking. Large-scale human activities, such as the discharge of household sewage and effluent, may be responsible for this. Therefore, it is important to protect river water by frequent monitoring and inspections of water quality to reduce human activities in this region.
REFERENCES


Acknowledgments

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