Application of fuzzy logic in river water quality modelling for analysis of industrialization and climate change impact on Sabarmati river

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ABSTRACT

Rivers are critical to human life because they are strategically significant in the world, providing primary water supplies for various purposes. Rivers are the prime importance of any country as most of the cities are settled near the river. Due to developmental activities and increase in population, it will result in huge waste generation. Surface water quality is affected because of increasing urbanization and industrialization. The aim of this research is to examine the effect of climate change and industrialization on the water quality of the Sabarmati river using a mathematical model. For this study, four important towns along the lower Sabarmati River have been considered and water quality data was considered from 2005 to 2015. In this study, different water quality parameters were considered to derive a water quality model. Results show the water quality downstream after Ahmedabad city is worse compared to the other location where the Maximum WQI is 0.71 at Rasi-kapur and average WQI is 0.50 for the same location for the last 15 years. It has been observed that the effect of the monsoon and also by comparing time scale water quality model the role of regulations for industrialization also plays an important role in the quality of Sabarmati river.

Key words: climate change, fuzzy logic, industrialization, water pollution, water quality model

HIGHLIGHTS

- Water quality modelling by using fuzzy logic approach for Sabarmati river.
- Calculate and analyze the WQI for Sabarmati River for the last 15-year time period.
- Analyze the impact of climate change and industrialization on river water quality.
- Comparison of the WQI mathematical model for the Sabarmati river.
- Analysis of self purification capacity of river using strength of Sabarmati river.
Without water, it is not possible to survive on the earth. In all species, around 70% of their weight is attributed to water. Water is available at many places but the fresh water is very limited and year by year it is getting contaminated. In certain places, like deserts, groundwater is the main supply of water. About 80% of all available water is used in the irrigation sector (Jackson et al. 2018). Rivers are essential sources of surface water, and India is a fortunate nation that is appropriately known as the ‘Land of Rivers’ because of the many rivers and lakes that crisscross the topography and scenery. Rivers, in addition to being a source of fresh water, play an important role in the absorption and movement of municipal and industrial waste water. Riverine sediments are significant pollutant accumulators that frequently represent the history of river pollution (Abdel-Satar et al. 2017). In aquatic settings, sediments serve as both transporters and sinks for pollutants. Domestic and industrial sewage, as well as agricultural pollutants, have been found to contaminate almost all Indian rivers, according to studies (Boholm & Prutzer 2017). The majority of these rivers have been converted into sewer drains. This presents a significant health risk to millions of people who continue to rely on contaminated river water. Gujarat’s major rivers are the Sabaramti, Naramada, Mahi, Tapti, and Purna. Prolonged and wasteful use of fresh water resources results in water scarcity problems due to lack of supply in desert regions or regions distant from water sources. Water must be conserved in other locations to keep up with the rising demand. Because of agricultural activities that utilize fertilizers and pesticides, groundwater is put at danger of pollution (Al-Safi & Sarukkalige 2017). Thus, preventing pollution of groundwater has become a major issue. The river water quality is the term used to measure how much water remains in the natural reservoir after a water treatment plant has extracted the useful portion. The aquatic life is extracted from the overall water consumption, and the resulting amount is the surplus water (Diamantini et al. 2018). By extension, research also examines the molecular, chemical, and physical characteristics of water in regard to its environment. While the river water level is sometimes unstable, water typically contains high concentrations of dissolved ions, particulate debris, and living organisms. In terms of expansion, human activities, and hydrological watershed, the qualities vary (Islam et al. 2014; Guettaf et al. 2017).
One method for evaluating river water quality is the water quality index. Water quality measurements have been shown to be very accurate and useful. Policymakers will know the typical quality of water by using this method of AQI (Hutchins et al. 2018; Islam et al. 2018). Various scientists have given different equations for the calculation of WQI (Bassin et al. 2009). WQIs have been calculated using a variety of different techniques based on the river catchment and its characteristics (Kumar et al. 2017; Lutz et al. 2016). A variety of water quality indexes may be found throughout the world, including the NSFWQI, the CCMEWQI, the BCWQI, the OWWQI, and the WAWQI (Cox et al. 2015). To compute water quality indices, we often need to assess two different variables. To begin, water quality parameters are converted into sub-index values. In the second stage, the water quality index is calculated by adding the sub-index values from stage one together. Water quality indicators are the subject of much research in the literature (Nasiri et al. 2007; Miller & Hutchins 2017; Patel et al. 2020). While Bhargava presented the first-ever water quality index in India, which rated water from highly contaminated to unpolluted water, the scale for that index ranged from 0 to 100. (Couture et al. 2018; Patel et al. 2020). Many studies have been conducted on different rivers’ water quality in India, and the results were then evaluated for human consumption (DeNicola et al. 2015; Clifton et al. 2018). Very little attention has been paid to the Sabarmati River’s uniformity. Water quality indexes, such as the Drinking Water Quality Index, have been used to assess the appropriateness of the Sabarmati River water for human consumption.

The WQI is measured using the summation of the several water quality characteristics and describes the total effect on water quality (Mohan & Jairaj 2016). A Water Quality Index is a tool used to depict an insightful and comprehensive data set, and does so by displaying the standard that is defined for that water quality. Water quality must be assessed for irrigation purposes using a variety of factors. Difficulty in comprehending may be especially tricky for individuals who have no previous expertise in the area of water (Nepal 2016). When it comes to water quality, this kind of research uses techniques that consider the overall effect of various factors. It is no longer uncommon to employ one of these methods for water quality assessment and measurement, which is called the Water Quality Index (WQI). The specifics of water quality variables have historically been computed and compiled into a dimensionless value that has a standard scale that ranges from the lowest level of poor water quality to the highest level of excellent water quality (Srinivas et al. 2015; Rao et al. 2019). WQI implementations may vary greatly, from little snippets to huge libraries. The first example of this kind of design appeared in 1965. This WQI incorporates a combination of 10 environmental variables that affect water quality.

Wastewater is generated by rapid urbanization and industrialization. Wastewater management has caused significant water contamination problems due to improper standards. Because of industrialization, urbanization, and climate change, the water quality and quantity have been threatened (Tirkey et al. 2013). As a result of human activities, the quality of surface water has deteriorated. The surface water’s natural self-purification mechanism could not work since the wastewater volume is high and the quality is too deteriorated (Sasikumar & Mujumdar 1998). The seasonality of the quality parameter has a big impact on the self-cleansing process. Quality parameter in surface water also varies depending on the seasonal fluctuation. To determine a river’s suitability and viability, both the amount and consistency of its water must be weighed. The two will assist in defining a river’s intrinsic potential, determining its stability, determining its capacity for self-repair while unsettled, and determining the amount of management assistance needed (Sahoo et al. 2015; Srinivas & Singh 2017).

There are several water quality index models that indicate the consistency of surface water. After 1965, when the first numerical water quality index (WQI) was developed, a number of additional water quality indices have been developed. The quality of surface water depends upon different parameters, and there is so much uncertainty in the behaviour of these parameters. Fuzzy logic addresses these uncertainties, for example when you define that average height of a person, this term is very different depending on different cultures. This uncertainty is addressed in a fuzzy model by defining variables including the range rather than a single number. This study aims to understand the impact on surface water quality due to industrialization and climate change using a Fuzzy Water Quality Index Model. This research will provide a detailed idea about (i) Water Quality modelling by using the fuzzy logic approach for Sabarmati river; (ii) help in calculating and analyzing the WQI for Sabarmati River for the last 15-year time period; (iii) analyze the impact of climate change and industrialization on river water quality; (iv) compare the WQI mathematical model for the Sabarmati river and analyze the self-purification capacity of the river using the strength of Sabarmati river as presented in this paper.

**STUDY AREA**

The Sabarmati River is the lifeblood of Ahmedabad, serving as a means of irrigation and drinking water as well as a disposal site for urban and industrial waste. Ahmedabad is regarded as Gujarat’s economic and political hub, with the largest
number of textile factories, posing a significant problem for the healthy drainage of factory and sewage effluents from various sources. The standard of river water in Ahmedabad has deteriorated as a result of the evolving climate and increased social and industrial activities, both of which have a direct or indirect impact on water quality (Patel et al. 2020; Patel & Shah 2020). The Sabarmati river is one of the four major rivers that pass across Gujarat’s alluvial plains. It rises at an elevation of 762 meters above mean sea level in the Aravalli hills in Rajasthan State, at a north latitude of 24°40’ and an east longitude of 73°20’. The river reaches Gujarat State after a 48-kilometer journey across Rajasthan and empties into the Arabian Sea’s Gulf of Cambay (Patel 2018; Patel et al. 2020). The Sabarmati River, which flows from north to south across the heart of the city for around 20–22 kilometers, is a significant source of water for the city’s various sectors (Patel 2020; Patel & Patel 2021). Figure 1 shows the locations of the sample points.

For this study, four sites were chosen from the Sabarmati basin Site 1 (Dharoi Dam) is upstream, while Site 2 (Gandhinagar) and Site 3 (Ahmedabad) reflect the river’s mid and downstream, respectively and Site 4 is Rasikapur downstream of the industrial area of Vatva, Ahmedabad city.

**METHODOLOGY**

The fuzzy water quality index model is developed for the selected study area. The fuzzy method is used for developing a Water quality Index considering the uncertainty of the quality parameters of the river. Two upstream and two downstream points are selected for calculating the WQI of the river. The location is selected to understand the impact of urbanization over this time period. Also the pre monsoon and post monsoon data is considered for each location to identify the impact of climate on river water quality. The attempt has been done in this present study to analyze the water quality of the river for urbanization and climate change impacts over 15 years of time period.

The water quality crisp data of four locations is converted into fuzzy data using fuzzy numbers defined for each parameter based on expert’s opinion. Fuzzy score is calculated for each parameter using the CPCB discharge parameter standard. Then fuzzy score of the parameter is multiplied with the weightage of each parameter. The sum of these products for each parameter represents the quality of surface water by a single number as the index. The detail of the Water Quality Index model is discussed in the next section (Figure 2).

WATER QUALITY INDEX MODEL

For developing the Water Quality Index, the Sabarmati river basin is selected. A total of four stations of the river basin were considered for this model. Two stations from upstream and two stations from downstream were selected for the model. A total of 10 water quality parameters as shown in the table with CPCB quality criteria are selected for the fuzzy Water Quality Index model. The crisp data of the selected four stations for the years 2005, 2010 and 2015 for the pre- and post-monsoon season are converted into fuzzy data (Figures 3, 4 and 5).

The next step in developing this model was defining the type of fuzzy numbers and finding the membership function for different parameters. Figure 6 shows the fuzzy trapezoidal number defined for the water quality index model. In Figure 6 linguistic variables are defined as follows: NS: Not Significant, LS: Low Significance, AS: Average Significance, S: Significant and VS: Very Significant.

After defining fuzzy numbers, a Fuzzy aggregate score is calculated for different parameters by considering Expert’s opinion and Fuzzy linguistic variables (see Supplementary Material).

As shown in Table 1, the average fuzzy aggregate score for 10 water quality parameters.

Based on this fuzzy aggregated score, the weightage of each parameter is calculated for the WQI model.

Crisp data of water quality parameters for selected four location is then normalized using GPCB limit as per given in below Table 2.

Table 3 shows the average value of Fuzzy score of each parameter for the pre-monsoon stage for each four location for 2005, 2010 and 2015.

This normalized fuzzy score is multiplied with the weightage of each parameter, as given in Table 2. This normalized value, if it is near to 1, shows the parameter exceeded the given GPCB limit. For example, if TDS is higher than 2,100 mg/L, the normalize value will be equal to 1. Each score calculated for these parameters is added and the final score represents the
Figure 3 | Water quality parameters: pH, E.C, D.O and temperature from 2005 to 2015.
Figure 4 | Water quality parameters: Total Hardness HCO₃, TDS and Total Alkalinity from 2005 to 2015.
Fuzzy water quality index. Table 4 shows the average WQI calculated for each location for the 2005 year pre-monsoon stage.

\[
\text{Fuzzy WQI} = \sum (w_i \times q_i)
\]

where, \(w_i\) = weightage of parameter and \(q_i\) = quality parameter fuzzy score.

RESULTS AND DISCUSSION

Fuzzy WQI calculated for different stations of Sabarmati River is represented in Figure 7. For the Fuzzy WQI calculated in this model, if the value is near zero it indicates the strength of the water is good and if the value is near to one, it indicates the strength of water is poor. This Fuzzy WQI shows a single parametric value as the result of all parametric quality strength aspects considering the weighted average method. In this research model, we have considered the timeline as well as upstream and downstream points of the Sabarmati River. The result at various points and for different time period shows the impact of industrialization and climate change on river water quality. Also it is observed that there is a seasonal difference
in water quality and location; also downstream quality is poor compared to upstream water quality. The result also shows the effect of exceeding a parametric value which impacts the final Fuzzy WQI value. The intensity of the impact on Fuzzy WQI will depend upon the weightage of the parameter identified in the Fuzzy WQI model. For example, Hardness and Total Alkalinity has a weightage of 0.131 and if the parametric value exceeds this, then for the GPCB limit the corresponding value will be taken as 0.1 as per the Fuzzy WQI model calculation. Now, this is multiplied by its weightage 0.131 and will have a consequent impact on the final WQI value. It is very important to determine the weightage of parameters according to the end purpose of the WQI value use. In this model, the objective of developing Fuzzy WQI

Figure 6 | Fuzzy trapezoidal numbers for linguistic variables.

Table 1 | Fuzzy aggregated score of WQI parameters

<table>
<thead>
<tr>
<th>Water quality parameter</th>
<th>Fuzzy aggregated score</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0.85</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.65</td>
</tr>
<tr>
<td>EC</td>
<td>0.45</td>
</tr>
<tr>
<td>TDS</td>
<td>0.85</td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>0.65</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>0.85</td>
</tr>
<tr>
<td>DO</td>
<td>0.85</td>
</tr>
<tr>
<td>Ca</td>
<td>0.45</td>
</tr>
<tr>
<td>Mg</td>
<td>0.45</td>
</tr>
<tr>
<td>SAR</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table 2 | WQI parameters: weightage and GPCB standard value

<table>
<thead>
<tr>
<th>Water quality parameter</th>
<th>pH</th>
<th>E.C</th>
<th>DO</th>
<th>Temp</th>
<th>TDS</th>
<th>Total Alkalinity</th>
<th>Total Hardness</th>
<th>Ca</th>
<th>Mg</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weightage (wi)</td>
<td>0.131</td>
<td>0.069</td>
<td>0.131</td>
<td>0.100</td>
<td>0.131</td>
<td>0.100</td>
<td>0.131</td>
<td>0.069</td>
<td>0.069</td>
<td>0.069</td>
</tr>
<tr>
<td>CPCB quality parameter criteria limit</td>
<td>6.5–8.5</td>
<td>2500</td>
<td>6</td>
<td>30</td>
<td>2000</td>
<td>600</td>
<td>600</td>
<td>200</td>
<td>100</td>
<td>0.26</td>
</tr>
</tbody>
</table>
is to study the impact of urbanization and climate change on Sabarmati river water quality and so accordingly the weightage of parameters are considered. This model helps to understand the strength of river water quality at different locations and for different time periods.

**Table 3** | Water quality parameter fuzzy score

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>pH</th>
<th>E.C</th>
<th>DO</th>
<th>Temp</th>
<th>TDS</th>
<th>Total Alkalinity</th>
<th>Total Hardness</th>
<th>Ca</th>
<th>Mg</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Dharoi</td>
<td>0.50</td>
<td>0.13</td>
<td>1.00</td>
<td>0.63</td>
<td>0.10</td>
<td>0.34</td>
<td>0.20</td>
<td>0.12</td>
<td>0.15</td>
<td>1.00</td>
</tr>
<tr>
<td>2005</td>
<td>Gandhinagar</td>
<td>0.73</td>
<td>0.09</td>
<td>0.88</td>
<td>0.83</td>
<td>0.06</td>
<td>0.17</td>
<td>0.12</td>
<td>0.06</td>
<td>0.10</td>
<td>1.00</td>
</tr>
<tr>
<td>2005</td>
<td>Ahmedabad</td>
<td>0.53</td>
<td>0.08</td>
<td>0.85</td>
<td>0.93</td>
<td>0.09</td>
<td>0.28</td>
<td>0.19</td>
<td>0.10</td>
<td>0.15</td>
<td>1.00</td>
</tr>
<tr>
<td>2005</td>
<td>Rasikapur</td>
<td>0.92</td>
<td>0.12</td>
<td>0.95</td>
<td>0.97</td>
<td>0.30</td>
<td>0.28</td>
<td>0.42</td>
<td>0.32</td>
<td>0.22</td>
<td>1.00</td>
</tr>
<tr>
<td>2010</td>
<td>Dharoi</td>
<td>0.07</td>
<td>0.17</td>
<td>0.77</td>
<td>0.67</td>
<td>0.20</td>
<td>0.77</td>
<td>0.49</td>
<td>0.18</td>
<td>0.49</td>
<td>1.00</td>
</tr>
<tr>
<td>2010</td>
<td>Gandhinagar</td>
<td>0.20</td>
<td>0.15</td>
<td>0.78</td>
<td>1.00</td>
<td>0.12</td>
<td>0.28</td>
<td>0.19</td>
<td>0.06</td>
<td>0.19</td>
<td>1.00</td>
</tr>
<tr>
<td>2010</td>
<td>Ahmedabad</td>
<td>0.33</td>
<td>0.36</td>
<td>1.00</td>
<td>0.77</td>
<td>0.10</td>
<td>0.48</td>
<td>0.29</td>
<td>0.14</td>
<td>0.24</td>
<td>1.00</td>
</tr>
<tr>
<td>2010</td>
<td>Rasikapur</td>
<td>0.59</td>
<td>0.94</td>
<td>1.00</td>
<td>0.87</td>
<td>1.00</td>
<td>0.53</td>
<td>0.45</td>
<td>0.14</td>
<td>0.49</td>
<td>1.00</td>
</tr>
<tr>
<td>2015</td>
<td>Dharoi</td>
<td>0.33</td>
<td>0.39</td>
<td>1.00</td>
<td>0.70</td>
<td>0.29</td>
<td>0.43</td>
<td>0.35</td>
<td>0.12</td>
<td>0.37</td>
<td>1.00</td>
</tr>
<tr>
<td>2015</td>
<td>Gandhinagar</td>
<td>0.20</td>
<td>0.04</td>
<td>1.00</td>
<td>0.80</td>
<td>0.08</td>
<td>0.13</td>
<td>0.10</td>
<td>0.08</td>
<td>0.05</td>
<td>1.00</td>
</tr>
<tr>
<td>2015</td>
<td>Ahmedabad</td>
<td>0.33</td>
<td>0.13</td>
<td>1.00</td>
<td>0.87</td>
<td>0.11</td>
<td>0.28</td>
<td>0.19</td>
<td>0.10</td>
<td>0.15</td>
<td>1.00</td>
</tr>
<tr>
<td>2015</td>
<td>Rasikapur</td>
<td>0.53</td>
<td>0.25</td>
<td>0.72</td>
<td>0.90</td>
<td>0.50</td>
<td>0.31</td>
<td>0.34</td>
<td>0.20</td>
<td>0.24</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Table 4** | Fuzzy WQI for Sabarmati river

<table>
<thead>
<tr>
<th>Location</th>
<th>Water quality parameter Normalized Fuzzy score * weightage of parameter</th>
<th>WQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dharoi</td>
<td>0.07 0.01 0.13 0.06 0.01 0.03 0.03 0.01 0.01 0.07 0.43</td>
<td></td>
</tr>
<tr>
<td>Gandhinagar</td>
<td>0.10 0.01 0.12 0.08 0.01 0.02 0.02 0.00 0.01 0.07 0.42</td>
<td></td>
</tr>
<tr>
<td>Ahmedabad</td>
<td>0.07 0.01 0.11 0.09 0.01 0.03 0.02 0.01 0.01 0.07 0.43</td>
<td></td>
</tr>
<tr>
<td>Rasikapur</td>
<td>0.12 0.01 0.12 0.10 0.04 0.03 0.05 0.02 0.02 0.07 0.58</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 7** | Water Quality Index for Sabarmati River for year 2005–2015.
Compared to upstream, downstream WQI values are poor for 2005, 2010 and 2015 year data. Pre-monsoon WQI values are higher than post-monsoon upstream due to dilution effect. However, for downstream points there is a peak in pre and post monsoon WQI and there is not much difference observed. This is due to rapid industrialization and waste water being discharged generally downstream, which indicates poor WQI values. Also, if we compare the impact of climate change and urbanization on water quality, the calculated WQI reflects changes over different locations and years along with seasonal changes. Comparing the WQI of upstream points of Dharoi and Gandhinagar stations for 2005 and 2010, there is not much significant difference, whereas for downstream points the WQI values are quite high in 2010 at the Rasikapur location. As compared to the 2010 WQI at Rasikapur, a significant change is observed in 2015. For Dharoi, Gandhinagar and Ahmedabad these three locations' WQI values are in similar ranges for 2005, 2010 and 2015.

There is improvement in water quality at the Rasikapur location within five years of duration. This result shows the outcome of efforts taken for waste water treatment before discharging it to the river and also focusing on water quantity improvement helps surface water quality overall. DO, the main pollution indicator, exhibited a wide range of values for the Raskapur station in the current research. For year one, the DO went as low as 0 mg/L from April until the end of the year. In addition to household sewage and industrial wastewater, it seems that an increase in the organic load at this station was necessary owing to the discharge of raw sewage and effluent from industry into the river. As the weather becomes warmer, the temperature of the stream rises. The solubility of oxygen in water increases as the water becomes warmer. The temperature also influences the bacterial metabolism, growth, and reproduction. With rising temperature, the rate of biodegradation and biological activity rises. To put it another way, oxygen demand in the water rises as a result. Due to very high organic pollution levels and a decrease in flow, the zero DO level was reached at Rasikapur. DO levels at Dharoi, Gandhinagar, and Ahmedabad were determined to be suitable for aquatic life survival throughout most of the months of 2015. Reduction in DO levels may be due to an increase in organically-polluted river water, which is discharged into the river during this time period. pH varied from 6.5 to 8.9 in the current research. For all stations, the narrowest fluctuation in pH is recorded. Variation in free CO2 is likely at a minimum at these times. TDS is the total dissolved solids (TDS) in water. Gandhinagar Station had lower EC values than the other stations in this research. It may be because the topsoil is more protected here, thus less erosion of the topsoil occurs. Rasikapur and Ahmedabad both exhibit significant EC levels, especially in April. This is probably because the riverbanks are heavily contaminated by sewage flow and human activity during the summer months. At the downstream stations, the TDS content is higher.

The results obtained by the fuzzy mathematical model was compared with the other model developed by the researcher for the Sabarmati river water quality analysis. A few research studies have been carried out for water quality analysis in the past; based on their results it has been summarized that river water quality is deteriorated after the Vasana barrage as the industrial development is increasing year by year and with respect to change in time and climate change effects the water quality is deteriorating in the lower part of the Yasna barrage; that is, Rasikapur. The average AQI value calculated by the different researchers for the same river 0.68 is the worst AQI reported at Rasikapur in the last 10-year period (Shah & Joshi 2017; Patel et al. 2020). Industrial effluent, lack of adequate sanitation, unprotected river sites, and urban runoff were the major causes of water quality degradation at these monitoring stations. In order to maintain water quality in the Sabarmati River, it is essential that frequent and thorough water quality monitoring be carried out by the state pollution control board. In order to obtain information relevant to developing pollution prevention programmes and identifying whether compliance with pollution regulations or implementation of effective pollution control actions are being met, there is a requirement to identify trends in water quality over time and across various locations.

**CONCLUSION**

This study attempts to understand the impact of urbanization and climate change on Sabarmati River water quality. For this study, we have considered 10 water quality parameters and effective weightage was considered for each parameter. From data it is observed that pH, dissolved oxygen, total hardness and total alkalinity parametric values are slightly higher at downstream locations of the river. The Fuzzy Water Quality Index calculated from the model has a range of 0.3–0.7, where a value near to zero shows good water quality. At Rasikapur location, which is in the downstream of Sabarmati river, the Fuzzy Water Quality Index value ranges from 0.45 to 0.7, which shows the effect of industrial effluent discharge on final river water quality, whereas at upstream points such as the Dharoi dam the Fuzzy Water Quality Index ranges from 0.5 to 0.7, which is an indication of less pollution load on the river compared to downstream. This Fuzzy WQI model shows the impact of urbanization and climate change on Sabarmati river water quality. The present study assesses the impact of climate conditions.
change and industrialization on river water quality using a Fuzzy logic approach. The emphasis should be given to water reuse and recycling, which will solve the problem of water scarcity as well as river water quality degradation.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES


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