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# Qualitative assessment of ground water using the water quality index from a part of Western Uttar Pradesh, North India

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**ABSTRACT**

Groundwater is the world's considerable resource for providing drinking water to millions of people worldwide. It is essential to assess groundwater quality for drinking water purposes due to the increasing trend of contaminants in this water. Therefore, this research has been carried out to study groundwater quality for 22 different village's well locations of Barauli Ahir block rural areas of Agra region, India, using the water quality indexing method. A total of sixty-six groundwater samples from identified areas were collected, selected as polluted ones. Twelve physico-chemical parameters were estimated to assess its eligibility for drinking purposes based on the drinking water quality index (WQI). The result shows that the groundwater was brackish, and the total dissolved solids ranged from 340–1,503 mg/L. The alkalinity varied between 142–531 mg/L, considered for the concentration of bicarbonate ions. The range of fluoride concentration is from 0.33 to 4.88; more than 45.4% of samples have a concentration of fluoride more significant than the WHO acceptable limit, that is, 1.5 mg/L. The water quality of drinking purposes was plotted in the Piper trilinear diagram, revealing that the water type at this study area was categorized as $Na^+/HCO_3^-$ or $Na^+/Cl^-$ type followed by $Ca^+/HCO_3^-$ type. Schoeller's diagram reveals that the concentration of magnesium and sulfate ions was least present among all cations and anions, which reveals that the hardness in water is low. The maximum and minimum value of the water quality index was found to be 233.16 and 49.80. The result of WQI showed that 41% of collected samples lie in the unfit water category, 45.5% of samples lie in the very poor category, 9% of samples lie in the poor category, and 4.5% of samples lie in the excellent category. This water quality index proved that it is necessary to treat water before using and protect the area from health hazards at Barauli Ahir block.

*Keywords:* Water quality index; Water monitoring; Groundwater; Agra rural area; Physico-chemical parameters

## 1. Introduction

Water is a fantastic substance essential for life on the earth, and there is a fixed supply of it on our planet. Potable and fresh water is necessary for human existence and the entire life. Groundwater is one of our freshwater resources, which is the major issue in front of the administrators for its sustainable consumption [1–5]. Several

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factors, including the water demand, the population increase, water scarcity at a higher altitude, are the biggest problems in many parts of the world [6]. The poor drinking water quality is generated by 80% of water-borne diseases globally. However, millions of people in numerous states of India, China, and Africa are mainly grieving from water-borne diseases [7,8]. The contamination and pollution of available water reserves are increasing due to population explosion, irrigation, and rapid industrialization [9]. The water quality is tainted due to the presence of numerous pollutants, either inorganic or organic, at concentrations beyond acceptable levels, causing problems to human health [10,11]. These factors indicate that it is needed to observe water quality and guard it against water pollutants. The water quality index (WQI) generally calculates Water quality. WQI is one of the most effective, easy, and simple comprehensible tools to measure water quality for its appropriateness for various purposes [12–14]. In 1970, Horton derived a mathematical expression by calculating values from different data sets to determine the water quality of a concerned area and named it the water quality index (WQI) [15–19]. It also defines the impact of diverse water quality factors on the general worth of water and outlines the critical indicators to determine the water quality [15]. WQI intends to give a means to the decision-makers to determine the water quality in terms of mathematical expression. Thus, it is possible to understand the interactions between different physio-chemical parameters to assess a sustainable environment [20–23].

The water quality index is the mathematical single scoring number of water and is calculated employing different methods. It is beneficial as decision-makers can decide the water quality and proper treatment technique [6,24–26]. Thus, it becomes a key aspect of the analysis of water quality programs. Since the water quality index is one of the most effective, easy, and straightforward comprehensive tools to measure water quality. Therefore this research work aims to assess the water quality. We selected 12 water quality parameters, measured monthly, 22 different villages were collected from identified and selected groundwater polluted areas from March 2016 to February 2019 to research the project water quality. The objectives of this study were (1) to provide an overview of present drinking water quality and compare it with the national and international standard, (2) to conduct a comprehensive evaluation of the water quality using the water quality index method of the groundwater at Barauli Ahir block.

## 2. Methodology

### *2.1. Study area*

The region of Agra is one of the highly groundwater contaminated areas on the Yamuna River bank in western Uttar Pradesh, North India (27.12° N latitude and 78.02° E longitude) Fig. 1. As per the 2011 Indian census, the Barauli Ahir block had a population of 2,74,601.

### *2.2. Physico-chemical parameters analysis*

Groundwater samples from 22 different villages were collected from identified and selected polluted areas to comprehend the study's objectives during December 2019 to May 2020, as shown on a map in Fig. 1. At each site, samples were collected in triplicates. Before the sampling, hand pumps were pumped out for about 5 min until all the physicochemical parameters stabilized. Total dissolved solids (TDS) and pH were determined at sampling sites through the Multi-Parameter kit provided by Iscon Instruments. Major ions

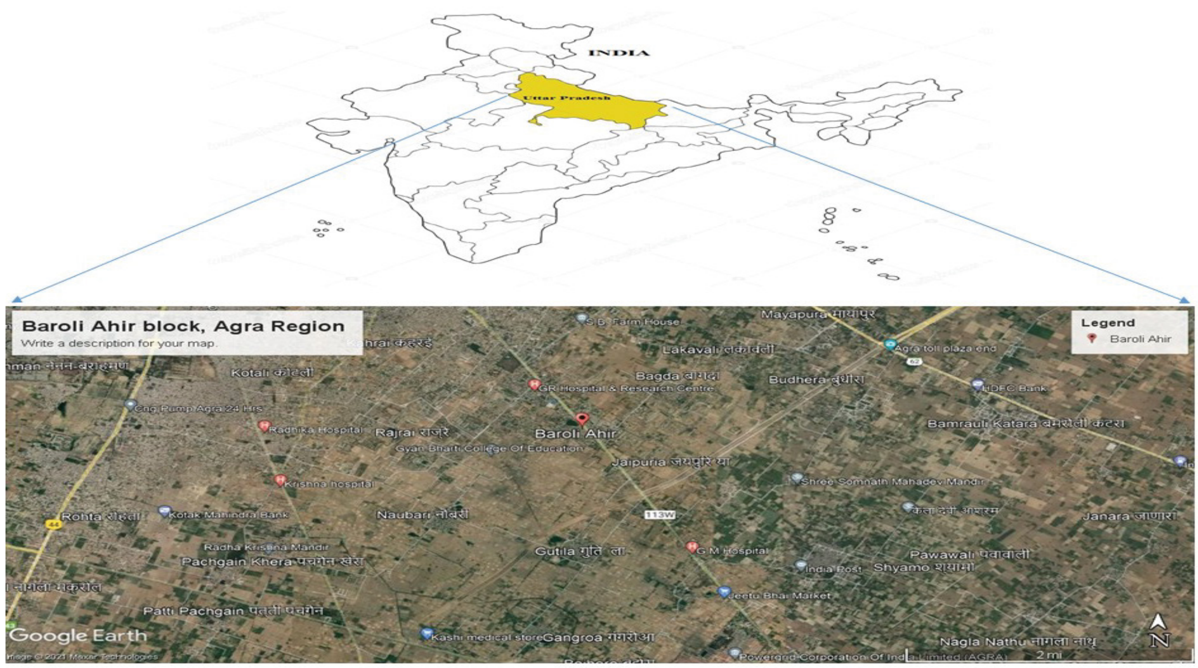


Fig. 1. Map of Barauli Ahir block, Agra district (Google Earth).

present in the samples were analyzed following standards procedures mentioned in APHA [27]. Alkalinity, hardness, calcium, and magnesium were estimated through titration methods, while a flame photometer was utilized to analyze sodium and potassium. Chloride was estimated by the silver nitrate titration method. A spectrophotometer analyzed sulphate and nitrate. The estimation of fluoride was measured with a specific analytical measurement instrument, Spectrophotometer UV-1800 Shimadzu APHA [27]. The accuracy of the results was validated by the ion balance of cation and anion checked, and the result was less than ±5%.

*2.3. Assessment and analysis of water quality index*

The water quality index (WQI) of Barauli Ahir block is evaluated by analyzing a range of physicochemical parameters such as $F^-$, pH, TDS, alkalinity, $Cl^-$, $Ca^{2+}$, $Mg^{2+}$, cations sodium ($Na^+$) and potassium ($K^+$), $NO^{3-}$ (nitrate), $SO_4^{2-}$ (sulfate) and T.H. (hardness) in different villages. To assess the eligibility of groundwater, the WQI was calculated for samples collected from the sixty various villages of the Barauli Ahir block. The drinking water standard as per WHO (2011) and IS 10500 (2012) has been given in Table 1.

The WQI has been evaluated to know the most expected quality variables. All the physicochemical parameters have been evaluated based on the standard procedure given in APHA [27]. Numerous steps of the weighted arithmetic index method are given following steps:

*2.3.1. Assessment of unit weight ($W_n$)*

The weights for numerous water quality parameters are presumed to be inversely proportional to the suggested values for the corresponding parameters [15,30,31].

The equation gives the formulation for weight calculation:

$$W_n = \frac{K}{X_s} \tag{1}$$

where $K = 1 / \sum X_s$

Table 1
Guidelines for potable water quality [28,29].

| Variables | WHO standards | IS 10500 standards |
|---|---|---|
| pH | 8.5 | 6.5–8.5 |
| TH, mg/L | 500 | 200–600 |
| $Ca^{2+}$, mg/L | 200 | 75–200 |
| $Mg^{2+}$, mg/L | 50 | 30–100 |
| $NO_3^-$, mg/L | 50 | 45 |
| $SO_4^{2-}$, mg/L | 250 | 200–400 |
| $K^+$, mg/L | 12 | – |
| $Na^+$, mg/L | 200 | – |
| $Cl^-$, mg/L | 250 | 250–1,000 |
| TDS, mg/L | 1,000 | 500–2,000 |
| TA, mg/L | 500 | 200–600 |
| $F^-$, mg/L | 1.5 | 1–1.5 |

where ($W_n$): unit weight for the *i*th parameter; ($X_s$): recommended standard for parameter and $i$ = 1, 2, 3, …, 16; and *K*: constant of proportionality.

*2.3.2. Assessment of quality rating ($Q_n$)*

A quality rating scale for each parameter was computed by dividing its standard concentration given by WHO guidelines.

$$\text{Quality rating } Q_n = 100 \times \frac{X_n - X_i}{X_s - X_i} \tag{2}$$

where $X_n$ = actual value of the parameter in a water sample; $X_i$ = ideal value of different water quality parameters (0 for all parameters except pH 7 mg/L); $X_s$ = standard value for the parameter.

*2.3.3. Assessment of quality rating for pH*

The following equation is used to calculate the quality rating of pH. However, the ideal value is 7 for pH (potable water), and an acceptable limit is 8.5 (contaminated water).

$$\text{Qn}_{\text{pH}} = 100 \times \frac{\text{Xn}_{\text{pH}} - 7}{8.5 - 7} \tag{3}$$

where $\text{Xn}_{\text{pH}}$ actual value of pH in a water sample.

*2.3.4. Assessment and calculation of water quality index*

$$\text{WQI} = \frac{\sum Q_n W_n}{\sum W_n} \tag{4}$$

The water quality index (WQI) generally differentiates drinking water into five categories: excellent, good, poor, inferior, and unsuitable [31–33], as shown in Table 2.

## 3. Results and discussions

*3.1. Groundwater chemistry of Barauli Ahir block*

Hydro-chemical properties of the groundwater of the urban areas of Agra are presented in Table 3. On the scrutiny of the data, it may be seen that (i) the pH of the groundwater samples varies from 7.2 to 8.7; about 63% of samples were within the acceptable limits, as specified by WHO and

Table 2
Classification of water quality index (WQI) values for drinking

| WQI range | Water type |
|---|---|
| >100 | Unfit for drinking |
| 76–100 | Very poor water |
| 51–75 | Poor water |
| 26–50 | Good water |
| 0–25 | Excellent water |

Table 3
Hydro-chemical properties of the groundwater of the urban areas of Agra

| Parameters | Minimum | Maximum | Mean | S.T.D.E.V. |
|---|---|---|---|---|
| pH | 7.2 | 8.7 | 8.05 | 0.47 |
| TDS | 340 | 1,503 | 933.55 | 316.39 |
| TA | 142 | 531 | 323.73 | 106.62 |
| TH | 40 | 380 | 187.73 | 83.36 |
| $Ca^{2+}$ | 13.45 | 132 | 65.5 | 30.57 |
| $Mg^{2+}$ | 1.94 | 44 | 10.49 | 10.12 |
| $Na^{+}$ | 45 | 422 | 242.91 | 134.5 |
| $K^{+}$ | 2 | 78 | 19.55 | 17.21 |
| $SO_4^{2-}$ | 22 | 127 | 66.41 | 26.49 |
| $Cl^{-}$ | 71 | 620 | 293.38 | 163.43 |
| $NO_3^{-}$ | 0.7 | 9 | 3.61 | 2.44 |
| $F^{-}$ | 0.33 | 4.88 | 1.81 | 1.03 |

All units are given in mg/L except pH.

BIS standards for potable water, that is, 6.5–8.5. The results depict that most of the groundwater samples are alkaline. (ii)The range of overall dissolved solids in the groundwater samples is from 340 to 1,503 mg/L with an average value of 933.55 mg/L (<500 mg/L TDS for potable water as per BIS.) which showed brackish water with a high dissolution of inorganic and organic components in groundwater. Arun Ram reported TDS values between 280–879 mg/L for drinking water Mahoba district is the south-western district of Uttar Pradesh [34]. El Mountassir et al. [35], reported that TDS ranged between 172.08–1,977.92 mg/L with a mean of 4,001 mg/L in Krimat aquifer. They reported that 77.78% of the sample location in this study area is unsuitable for drinking water according to WHO standards. (iii) The alkalinity varied between 142–531 mg/L with an average value of 323.73 mg/L, considered for bicarbonate ion concentration. Bicarbonate was the most dominant anion for most groundwater samples, while few samples have chloride ions as the prevailing anion. (iv) The range of total hardness concentration (T.H) as $CaCO_3$ of the groundwater sample from 40–380 mg/L with an average value of 187.73 mg/L. (v) The concentration of calcium and magnesium ions were ranged from 13.45–132 and 1.94–44 mg/L, with an average value of 65.5 and 10.49 mg/L. (vi) The range of sodium ion concentration is from 45 to 422 mg/L with an average value of 242.91 mg/L, and therefore it is the most prevailing among all the cations. (vii) The range of potassium ion concentration was 2.0, and 78 mg/L with an average value of 19.55 mg/L (viii) The concentration of sulphate ion ranges from 22 to 127 mg/L with an average value of 66.41 mg/L. (ix) The concentration of chloride ions ranged from 71–620 mg/L with an average value of 293.38 mg/L. (x) The range of concentration of nitrate is from 0.7 to 9.0 mg/L, and none of the groundwater samples indicated nitrate concentration greater than the acceptable limit of 45 mg/L [36].

Arun Ram reported that nitrate concentration ranges from 86.95 to 210.4 mg/L. It is over the permissible limits throughout the study area [34]. In the study area, nitrate concentration varies from 1 to 67 mg/L with an average of 15.96 mg/L [35].

The range of concentration of fluoride ions is from 0.33 to 4.88, with a mean value of 1.81. Among 110 samples, more than 45.4% of samples have a concentration of fluoride greater than WHO acceptable limit, that is, 1.5 mg/L, which may be due to the weathering of fluoride-rich mineral contents in the bedrocks and soil. Arun Ram reported that the fluoride concentration ranges from 0.11 to 3.91 mg/L. The fluoride concentration exceeds the permissible limit (1.5 mg/L) in about 25% of the groundwater samples [34]. Shahjad Ali et al. [37] conducted a study on the fluoride contamination and risk assessment of Agra; the result showed that the fluoride concentration in the study area ranged between 0.14 to 4.88 mg/L. Out of 73, the fluoride levels in 45 villages did not meet the acceptable Word Health Organization standards. According to Verma et al.'s research [24], the concentration of fluoride ions varies from 0.34 to 1.89 mg/L with an average of 1.08 mg/L.

### 3.2. Geochemical characterization at Barauli Ahir block

According to the piper diagram (Fig. 2), the common cations were sodium at most sampling points, followed by calcium and magnesium. About 86% of the samples have sodium ions as the significant cations. The most common anions were bicarbonates, followed by chloride. So the water type at the Barauli Ahir block was categorized as $Na^+/HCO_3^-$ or $Na^+/Cl^-$ type followed by $Ca^+/HCO_3^-$ type. The maximum amount of fluoride is commonly observed in sodium bicarbonate type water, showing fluorite dissolution in water with sodium bicarbonate. According to the Schoeller diagram (Fig. 3), ionic constituents of groundwater samples have been presented. The concentrations of the main ionic constituents in groundwater ($SO_4$, $HCO_3$, Cl, Mg, Ca, Na and K) in equivalents per million per kg of solution (mEq/kg) is the semi-logarithmic diagram, that is, Schoeller diagram. The points on six equally spaced lines denoted the concentration of each ion in each sample, and a line connects those points. The concentration of magnesium and sulfates ions was least present among all cations and anions, which reveals that the hardness in water is low.

### 3.3. Assessment of water quality index

#### 3.3.1. Spatial distribution of the water quality index

Fig. 4 presented the spatial distribution pattern of the water quality index (WQI). It was found that in the Barauli Ahir block, more than 41% of collected samples lie in the unfit water category, 45.5% of samples lie in the very poor category, while 9% of samples lie in the poor category, and 4.5% of samples lies in the excellent category. Based on the quality of water in different villages, the percentage distribution of different categories of groundwater in the present study area has been delineated through the Table 4. It may also be indicated that water quality parameters, mainly fluoride, chloride, alkalinity, and sodium, are greater than the acceptable W.H.O Guideline [28,36].

Table 4 shows the maximum and minimum value of the water quality index for various locations of the Barauli Ahir block; it can be seen that the maximum and minimum value of the water quality index is 233.16 and 49.80, delineated

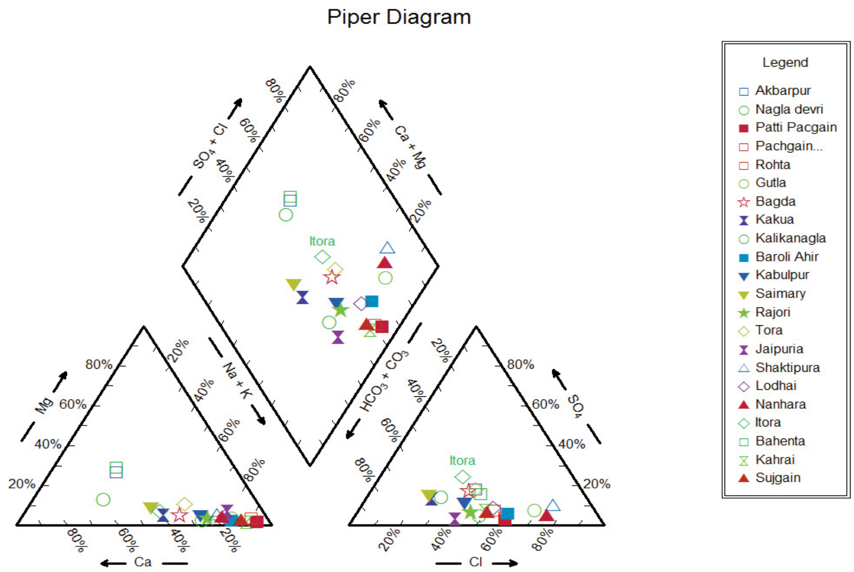


Fig. 2. Classifications of hydrochemical facies using the piper plot at Barauli Ahir block.

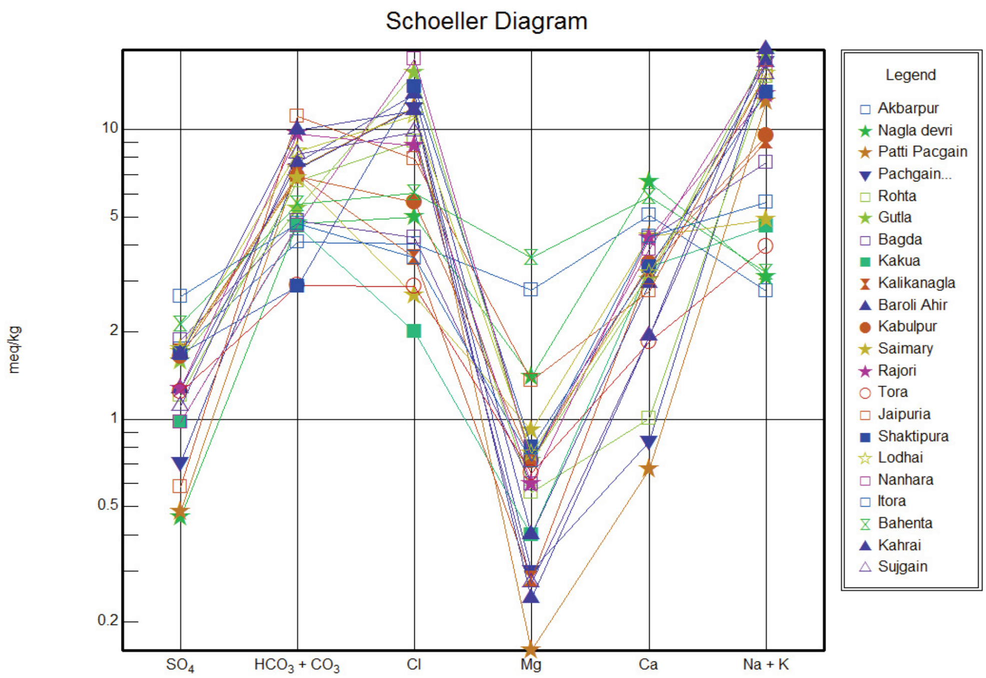


Fig. 3. Schoeller diagram of Barauli Ahir block.

as per Table 4. On careful scrutiny, it is established that the maximum value of WQI is in Pachgain Kheda village. However, the minimum value is in Itora village.

## 4. Conclusions

The analysis of physicochemical parameters of the groundwater of the Agra district was assessed to determine its suitability for drinking purposes using a water quality index. The resulting study of chemical and physical faces shows that the groundwater study area is brackish, and the total dissolved solids ranged from 340–1,503 mg/L. The alkalinity varied between 142–531 mg/L, considered for the concentration of bicarbonate ions. The range of fluoride concentration is from 0.33 to 4.88; more than 45.4% of samples have a concentration of fluoride greater than the WHO

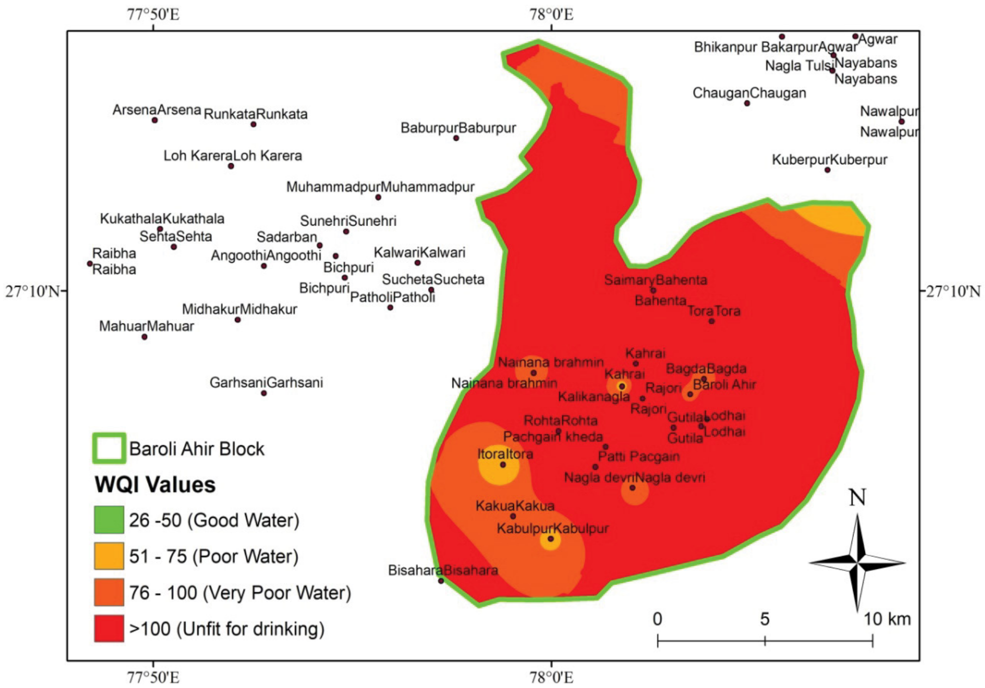


Fig. 4. Spatial distribution of WQI at Barauli Ahir block.

Table 4
WQI values for Barauli Ahir block

| S. No. | Name of the village | WQI | Water quality |
|---|---|---|---|
| 1 | Akbarpur | 93.69 | Very poor water |
| 2 | Nagla Devri | 77.88 | Very poor water |
| 3 | Patti Pachgain | 191.98 | Unfit for drinking |
| 4 | Pachgain Kheda | 233.16 | Unfit for drinking |
| 5 | Rohta | 176.17 | Unfit for drinking |
| 6 | Gutla | 98.78 | Very poor water |
| 7 | Bagda | 89.49 | Very poor water |
| 8 | Kakua | 86.03 | Very poor water |
| 9 | Kalika Nagla | 65.74 | Poor water |
| 10 | Baroli Ahir | 91.9 | Very poor water |
| 11 | Kabulpur | 69.44 | Poor water |
| 12 | Saimary | 177.08 | Unfit for drinking |
| 13 | Rajouri | 154.36 | Unfit for drinking |
| 14 | Tora | 157.99 | Unfit for drinking |
| 15 | Jaipuria | 171.36 | Unfit for drinking |
| 16 | Shaktipura | 85.78 | Very poor water |
| 17 | Lodhai | 95.99 | Very poor water |
| 18 | Nanhara | 89.73 | Very poor water |
| 19 | Itora | 49.80 | Good water |
| 20 | Bahenta | 80.56 | Very poor water |
| 21 | Kahrai | 144.69 | Unfit for drinking |
| 22 | Sujgain | 100.79 | Unfit for drinking |

guideline. Piper trilinear diagram reveals that the water type at this study area was categorized as $Na^+/HCO_3^-$ or $Na^+/Cl^-$ type followed by $Ca^+/HCO_3^-$ type. Schoeller's diagram reveals that the concentration of magnesium and sulfates ions was least present among all cations and anions, which reveals that the hardness in water is low. The result of the calculation of WQI showed that 41% of samples are classified as unsuitable for drinking water, 45.5% in the very poor category, 9% in the poor category, and 4.5% of samples lie in the good category. This classified water quality index proved that water pre-treatments before use are necessary to protect the area from health hazards at Barauli Ahir block. However, this result helps the regional decision markers manage, plan, and protect these groundwater resources.

## Conflict of interest

The authors declare that they have no conflict of interest.

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