

# **Assessment of Groundwater Quality in Selected Areas of Bangladesh: A Water Quality Index Approach**

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## **Abstract**

Groundwater is the main source of drinking water in Bangladesh. The majority of the people depend on the groundwater for drinking purposes, particularly in rural and semi-urban regions where the availability of treated surface water is restricted. However, over the years, industrialization has increased across the country. Agricultural runoff, poor sanitation practices, and poor waste management systems are concerning about groundwater standards. Groundwater standard has been threatened by both natural and human activities. This study focuses on assessing the groundwater condition in four major locations, such as Chandpur, Gazipur, Saver, and Chittagong, which represent several environmental and industrial conditions. Groundwater samples were collected from eight selected tube wells, two samples from each location, and were analyzed for key physicochemical parameters like pH, hardness, chloride, iron, arsenic, nitrate, turbidity, TDS, and fecal coliform. The results indicate that while most parameters, including pH, chloride, TDS, turbidity, and nitrate, remain within permissible limits, iron levels exceeded the standard mentioned in Environmental Conservation Rules (ECR) 2023 in Chandpur, Savar, and Chattogram. Additionally, severe fecal coliform contamination was detected in all regions, posing significant health risks. A water quality index was also assessed by the Weighted Arithmetic Water Quality Index (WAWQI) method and found poor groundwater quality in Gazipur and Chattogram and very poor in Saver & Chandpur.

## **Keywords**

Groundwater Quality, Water Quality Index (WQI), Physicochemical Parameters, Weighted Arithmetic Method, Fecal Coliform

## **1. Introduction**

One of the most essential natural resources is groundwater. It is playing a core role in securing livelihoods, food safety, and industrial development (Davis, 2003). Approximately 90% of citizens depend on groundwater for their drinking water, especially in rural and semi-urban areas (Kinniburgh & Smedley, 2001) where surface water is limited. Due to its relatively low cost, groundwater is being used for various purposes such as domestic, agricultural, and industrial activities. The various sources of drinking water are mainly surface water (rivers, lakes, and ponds), groundwater (aquifers and springs), glacial and snowmelt (melting of glaciers and ice caps in mountains), and rainwater. About 2.5% of the Earth's water is freshwater, but less than 1% is easily accessible to humans. Most of this resource is stored in glaciers and deep aquifers (Mishra & Dubey, 2015).

Groundwater quality is declining due to natural processes such as mineral extraction and human activities including pollution, over-extraction, and poor waste management (M. I. Hossain et al., 2025). Groundwater quality is reducing in various ways, including rapid urbanization, industrial discharge, agricultural runoff, and improper waste disposal systems. These issues create contamination such as arsenic, nitrate, iron, and fluoride (Ruidas et al., 2024). These contaminants pose serious risks to human health, causing diseases such as cancer, asthma, and respiratory problems.

One of the most hazardous contaminants is arsenic, and it is well documented. Arsenic is at the highest levels in the southern and southwestern regions, including areas like Chandpur, which are exposed to arsenic levels that are much higher than the WHO's safe level (Chowdhury, 2023). As a result, every year, millions of individuals are affected by various diseases in this area, such as skin problems, cancer, and cardiovascular diseases (Khalequzzaman et al., 2005). Similarly, both iron and nitrate pollution have become widespread in industrial zones, for instance, Saver and Gazipur, because of wastewater and agricultural activities (Momtaz et al., 2012).

Groundwater quality differs widely throughout the country due to factors such as local geological conditions, land use activities, population concentration, and closeness to pollution sources. Recognizing these spatial differences is crucial for developing effective, location-specific strategies to ensure access to safe drinking water (Alexander et al., 2017). In this regard, the Water Quality Index (WQI) is a useful method that allows for the evaluation and comparison of groundwater quality based on various indicators in a clear and standardized way.

### **1.1 Objectives**

The main objective of this study is to assess the quality of groundwater in four major locations of Bangladesh, such as Chandpur, Gazipur, Saver, and Chattogram. The research focuses on analyzing physical, chemical, and microbiological parameters to understand the current condition of groundwater. It also aims to calculate the Water Quality Index (WQI) to assign ratings of water quality.

## **2. Literature Review**

Groundwater is the core source of drinking and irrigation water in Bangladesh, which provides about 98% of the country's drinking water (Shamsudduha et al., 2019). Groundwater is available in shallow and deep aquifers that have been supporting various sectors such as agricultural production, industrial growth, and domestic consumption. On the other hand, both quality and sustainability have declined over the years due to rapid urbanization, industrialization, and population growth. Arsenic, iron, heavy metals, salinity intrusion, and microbiological contamination have emerged as critical public health and environmental challenges. Contaminated water cannot be used for drinking, household, and agricultural purposes due to serious health risks (Ahmed et al., 2025). This study emphasizes groundwater quality in Bangladesh, with particular areas like Chandpur, Chattogram, Saver, and Gazipur highlighting sources of contamination and regional vulnerabilities.

Groundwater plays a vital role for social and economic development in Bangladesh. Groundwater serves as the primary source of drinking water for about 98% of rural and 70% of urban households, with agriculture—especially rice cultivation consuming nearly 90% of the nation's supply (Shamsudduha et al., 2019). In industrial hubs such as

Gazipur and Savar, the growth of textile, tannery, and pharmaceutical industries has increased reliance on groundwater, and its levels declined annually by two meters owing to excessive extraction, which threatens water availability and water quality and promotes the movement of contaminants.

Arsenic remains the most infamous groundwater contaminant in Bangladesh and has been described by the World Health Organization as the “largest mass poisoning in history (WHO, 2011). Chandpur is among the districts most severely affected, where shallow aquifers (depths less than 100 meters) often contain arsenic concentrations that exceed both the Bangladesh standard of 50 µg/L and the WHO guideline of 10 µg/L. BGS and DPHE have shown in the national survey that Chandpur has the highest risk areas in the country (BGS Technical Report WC/00/19, 2001). Long-term consumption of arsenic-contaminated water causes a variety of diseases in people, including arsenicosis, skin disorders, and cancer (WHO, 2011).

Chattogram is the principal coastal and industrial city of Bangladesh, where groundwater faces threats from both natural and human activities (Miah et al., 2020). Coastal aquifers are increasingly affected by saltwater intrusion caused by climate change, sea-level rise, and tidal surges (Dasgupta et al., 2015). Studies indicate that groundwater salinity has increased sharply over the past two decades, rendering many shallow wells unfit for drinking and irrigation (Chowdhury et al., 2024). Industries like shipbreaking, steel, and chemical plants make the pollution worse because their untreated waste seeps into the groundwater. Rahman et al. (2017) and Hoque et al. (2019) found that groundwater quality is getting worse because of saltwater intrusion and waste released from industries (Hoque et al., 2019). Recent assessments in Mirsharai revealed that deep groundwater (>130 m) remains good to excellent, while shallow water is poor to unsuitable. In Patenga, TDS (1,220–8,650 mg/l) and chloride (up to 3,264 mg/l) exceeded drinking-water limits, confirming significant salinity intrusion (S. Hossain et al., 2016).

After the establishment of the Hazaribagh Tannery in Savar, industries have developed rapidly in Savar. The area’s environment is polluted with harmful metals like chromium, cadmium, and lead that come from nearby tanneries and textile dyeing factories (Nesha et al., 2023). Findings illustrate that chromium levels are escalating in the groundwater around the Savar tannery industrial area, which concerns serious health risks for local residents (Chamon et al., 2023). Textile waste is dangerous for the environment, as dyes and salts play a significant role in water pollution. It causes groundwater levels to drop, making the land more likely to sink and aquifers more vulnerable. Chromium concentrations have been reported between 0.46 and 1.12 mg/l, which exceeded the WHO guideline of 0.05 mg/l (Chamon et al., 2023). Moreover, high TDS values (above 1,200 mg/l) and elevated conductivity indicate severe pollution from effluents released into the surrounding aquifers.

Gazipur is located near Dhaka, which is a major industrial area in Bangladesh, including numerous textile, dyeing, and pharmaceutical factories (R. Parvin & Tanvir Ahmed, 2023). Groundwater is utilized as the main source for both industrial operations and domestic use. The use of fertilizers and pesticides in agriculture is responsible for nitrate pollution. Rubayet-ul-Islam and Alam (2025) discovered nitrate concentrations in shallow wells ranging from 12 to 45 mg/l, significantly exceeding the WHO threshold of 10 mg/l, primarily due to fertilizer application and industrial effluents (Rubayet-ul-Islam & Alam, 2025). Parvin (2019) reported a groundwater decline of 1.8–2.3 m per year due to over-extraction (M. Parvin, 2019), while Rahadujjaman et al. (2025) found TDS levels of 750–1,200 mg/l and poor WQI scores, indicating severe groundwater stress in Gazipur (Rahadujjaman et al., 2025).

Most studies focus on chemical pollution, but microbial contamination is still a big issue in Bangladesh that hasn’t been well studied. Researchers have often found fecal coliforms in shallow tube wells, particularly in busy areas like Savar and Gazipur, due to poor sanitation systems and frequent floods. S. H. Rahman et al. (2009) found that 30–70% of shallow wells (less than 36 m deep) in rural Bangladesh contained *E. coli* (Rahman et al., 2009). Similarly, Islam et al. (2020) found that wells within 10 meters of sanitation systems contained the most coliform bacteria (Islam et al., 2020). Subah et al. (2018) further noted that flooding events significantly increase microbial intrusion into aquifers. Unlike chemical pollution, microbial contamination can quickly lead to diseases like cholera, dysentery, and diarrhea, highlighting the need for better sanitation, regular water testing, and public awareness.

The Water Quality Index (WQI) is commonly used to measure overall water quality by combining physical, chemical, and biological factors into one score. It categorizes water as excellent, good, poor, or unsafe for drinking. The WQI method developed by Brown et al. (1972) has been used to assess the quality of groundwater. Rubayet-ul-Islam and Alam (2025) reported that WQI values in Gazipur ranged between 68 and 94, showing poor suitability for drinking.

Similarly, Rahadujjaman et al. (2025) found that high TDS (780–1,230 mg/l) and chloride (up to 550 mg/l) made the water quality much poorer (Rahadujjaman et al., 2025).

### 3. Methodology

#### 3.1 Study area and sampling locations

Groundwater samples were obtained from eight sampling points across four major locations: Moishadi and Baburhaat in Chandpur, Kapasia and Chadpurbazar in Gazipur, Nabinagar and Jamgora in Savar, and Vasanchar and Sandwip in Chattogram. These areas were chosen to reflect different natural and human-influenced conditions, such as industrial, agricultural, and coastal zones, to better understand how groundwater quality changes from place to place. Therefore, groundwater samples were collected from eight tube wells to study their hydrogeochemical properties and examine their suitability for drinking. Samples were collected from fully operational tubewells, which serve as the primary drinking water source for numerous households in the surrounding area.

#### 3.2 Sampling Strategy

Groundwater samples were accumulated from tubewells in two representative locations within each study area. Before sampling, the tubewells were pumped for five minutes to purge the standing water in the water tubes. Water was stored in sterile, dried 100 mL polyethylene bottles, sealed airtight to prevent any compositional changes from exposure to oxygen. The majority of the tubewells were dug at depths between 150 and 300 ft. to obtain fresh groundwater. Water samples were collected from 2 February 2025 to 20 February 2025 and sent for testing in the laboratory (Figure 1, Table 1).

Table 1. Geographical Coordinates of Groundwater Sampling Locations

Sampling Area	Sampling Site	Latitude (°N)	Longitude (°E)
Chandpur	Moishadi	23°13'57.8"	90°41'32.4"
	Baburhaat	23°15'30.0"	90°41'34.4"
Gazipur	Kapasia	24°06'45.4"	90°33'59.6"
	Chadpurbazar	24°02'46.5"	90°34'25.4"
Chattogram	Vasanchor	22°21'58.8"	91°22'30.3"
	Sandwip	22°29'02.9"	91°26'10.3"
Savar	Nabinagar	23°58'57.4"	90°15'39.4"
	Jamgora	23°56'12.7"	90°17'25.4"

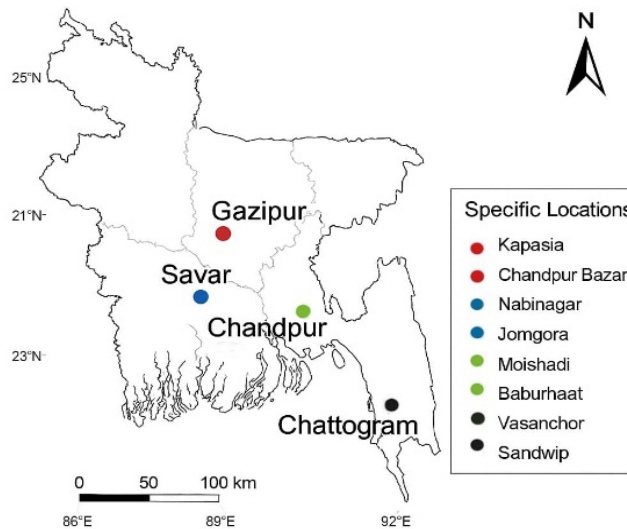


Figure 1. Location Map of Study Area

### 3.3 Laboratory analysis

The study tested nine parameters to assess the physical, chemical, and microbiological quality of groundwater. These parameters are divided into three categories, which are physical parameters (pH, turbidity, and total dissolved solids (TDS)), chemical parameters (hardness, chloride, nitrate, iron (Fe), and arsenic (As)), and fecal coliform as the microbiological parameter. Table 2 shows the methods used to analysis the water quality parameters.

Table 2. Parameters and Analytical Methods Used in Groundwater Analysis

Parameter	Unit	Instrument / Technique
pH	–	Digital pH meter
Turbidity	NTU	Turbidity meter
TDS	mg/l	Digital TDS meter
Hardness	mg/l	Spectrophotometer
Chloride	mg/l	Spectrophotometer
Nitrate	mg/l	Spectrophotometer
Iron (Fe)	mg/l	Spectrophotometer
Arsenic (As)	mg/l	Spectrophotometer
Fecal Coliform	CFU/100 mL	Membrane filtration

### 3.4 Statistical analysis

The Water Quality Index has been determined using the drinking water quality standard recommended by the ECR 2023. The WQI has been calculated using the weighted arithmetic method originally proposed by Horton (1965) and developed by Brown et al. (1972). The weighted arithmetic Water Quality Index (WQI) is represented in the following way.

#### 3.4.1 Calculation of Unit Weight

The unit weights ( $W_i$ ) of different water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$w_i = \frac{k}{s_n} \quad (1)$$

Where,  $w_i$  = unit weight for the  $i^{th}$  parameter,  $s_n$  = standard value for  $i^{th}$  parameters,  $k$  = proportional constant and can be calculated by equation (2).

$$K = \frac{1}{\sum_{i=1}^n \left(\frac{1}{s_n}\right)} \quad (2)$$

#### 3.4.2 Calculation of Quality Rating

According to Brown et al. (1972) the value of the quality rating or sub-index ( $Q_i$ ) is calculated using the equation as given below:

$$Q_n = \left| \frac{v_n - v_i}{s_n - v_i} \right| \times 100 \quad (3)$$

Here,  $Q_n$  is the quality rating for  $n^{th}$  parameter,  $v_n$  refers to the observed value of the  $n^{th}$  parameter and  $v_i$  represents the ideal value for the  $n^{th}$  parameter in pure water. Note that  $v_i = 0$  for all the parameters except for  $pH$  ( $v_i = 7$ ) and  $DO$  ( $v_i = 14$ )

#### 3.4.3 Calculation of WQI

The weighted arithmetic Water Quality Index (WQI) is represented in the following way.

$$WQI = \frac{\sum Q_n w_i}{\sum w_i} \quad (4)$$

Table 3 shows the classification of Water Quality Index (WQI) values and their corresponding water quality conditions. WQI values from 0 to 25 are categorized as Excellent, meaning the water is suitable for all purposes without any treatment. The range 26–50 indicates good quality, where water is safe with minor issues. A fair rating (WQI 51–75) suggests that the water is usable only after proper treatment. Poor water (WQI 76–100) is unsafe without treatment and may pose health risks. WQI values above 100 are considered Very Poor, meaning the water is unsuitable for most uses due to high contamination levels.

Table 3. WQI Range and Their Corresponding Meanings

WQI Value	Category	Water Quality
0–25	Excellent	Suitable for all purposes
26–50	Good	Minor issues, safe
51–75	Poor	Suitable with treatment
76–100	Very Poor	Unsafe without treatment
>100	Unsuitable for Drinking	Unsuitable for most uses

The water quality index (WQI) with corresponding water quality status as proposed by Brown et al. (1972) is demonstrated in Table 3 (Brown et al., 1972).

### 3.5 Data Interpretation

The water quality index values calculated and separated various categories such as excellent, good, poor, very poor, and unsuitable to assume groundwater suitability for drinking. The data were compared across the four regions to realize geographical variances and chief pollution sources.

## 4. Results and Discussion

### 4.1 Analysis of Different Quality Parameters

Table 4 shows the results of water samples at different locations. The pH values across all sampling sites range from 7.2 to 7.9, indicating that the water is neutral to slightly alkaline. Samples from Savar show the highest pH (7.9), while Gazipur, Chandpur, and Chattogram are closer to neutral. Chloride levels are highest in Chattogram (316 mg/l), probably due to its coastal influence, whereas Gazipur, Chandpur, and Savar have the lowest values, ranging from 10 mg/l to 120 mg/l. TDS is also highest in Chattogram (536 mg/l), reflecting more dissolved minerals, and lowest in Savar (60 mg/l), indicating cleaner water. Iron levels are the highest in Chattogram (2.06 mg/l), Savar (2.04 mg/l), and Chandpur (2.0 mg/l), exceeding the safe threshold set by ECR. Turbidity is slightly higher in Gazipur (1.75 NTU), while Savar has the lowest (0.29 NTU). Nitrate levels are low (0.0–0.86 mg/l), highest in Gazipur, while hardness ranges from 84 to 395 mg/l. The fecal coliform counts ranged from 0 to 30 CFU/100 ml, showing a serious health concern.

Table 4. Laboratory Test Results of Water Samples at Different Locations

Parameters	Gazipur		Chandpur		Savar		Chattogram	
	Chandpur Bazar	Kapasias	Maishadi	Baburhaat	Nabinagar	Jamgora	Swandip	Vasanchor
pH	7.4	7.2	7.3	7.5	7.9	7.8	7.4	7.5
Chloride (mg/l)	10	60	70	50	10	120	300	316
TDS (mg/l)	132	139	272	294	60	93	84	536
Iron (mg/l)	1.01	1.05	1.03	2.0	1.07	2.04	2.06	1.04
Arsenic (mg/l)	0.005	0.005	0.010	0.05	0.01	0.00	0.00	0.00
Turbidity (NTU)	1.38	1.75	1.25	0.43	0.29	0.41	1.20	0.72
Nitrate (mg/l)	0.86	0.443	0.0	0.443	0.443	0.0	0.0	0.0886

<b>Hardness (mg/l)</b>	141	181	304.2	395.3	127.5	84	127.5	127.5
<b>Fecal Coliform CFU/100 mL</b>	6	0	5	13	8	4	20	30

The Table 5 shows the average water quality parameters of Gazipur, Chandpur, Savar, and Chattogram compared with the Bangladesh ECR 2023 standards.

The water quality data for Gazipur indicate that most chemical parameters are within the acceptable limits defined by the ECR 2023. The pH value was 7.3, falling within the standard range. Total dissolved solids were measured at 135.5 mg/L and turbidity at 1.56 NTU, both well below the permissible limits. Arsenic and nitrate were also very low at 0.004 mg/L and 0.65 mg/L, respectively, and chloride was 35 mg/L, showing no concern. Hardness was recorded at 147 mg/L, remaining within the acceptable level. However, iron was found to be 1.01 mg/L, which slightly exceeds the maximum allowable limit. Additionally, fecal coliform was present with a count of 3 CFU/100 mL, which is unsafe as per ECR 2023, which requires zero presence.

In Chandpur, water quality is mostly acceptable chemically, with the pH at 7.4, total dissolved solids at 283 mg/L, and turbidity at 0.84 NTU, all below the maximum permissible limits. Arsenic was 0.02 mg/L and nitrate 0.22 mg/L, both within the safe range. Chloride was measured at 65 mg/L and hardness at 304.9 mg/L, remaining below the standard. However, iron concentration was significantly high at 1.51 mg/L, exceeding the upper limit. A severe concern was observed in microbial contamination, with fecal coliform detected at 9 CFU/100 mL. This high count indicates unsafe drinking water quality, and therefore, water from Chandpur requires treatment before use.

Savar demonstrated the lowest water quality among the assessed locations. Although the basic parameters such as pH at 7.8, total dissolved solids at 76.5 mg/L, and turbidity at 0.35 NTU were well within the acceptable ranges, elevated levels of iron and extreme microbial contamination were observed. Iron content reached 1.54 mg/L, the highest among all areas, significantly exceeding the allowable maximum limit. While arsenic was 0.004 mg/L, nitrate 0.22 mg/L, chloride 30 mg/L, and hardness 84 mg/L, all within permissible limits, fecal coliform contamination was extremely high at 6 CFU/100 mL. This indicates severe microbiological pollution, making the water highly unsuitable for drinking unless properly treated.

In Chattogram, the water quality is generally acceptable in terms of chemical parameters. The pH was 7.4, total dissolved solids 310 mg/L, and turbidity 0.96 NTU, showing compliance with standards. Arsenic was not detected, and nitrate was 0.443 mg/L, indicating no concern. Chloride, at 210 mg/L, and hardness, at 127.5 mg/L, were also within the permissible limits. However, iron concentration was 1.49 mg/L, slightly higher than the acceptable limit. The presence of fecal coliform, with a count of 25 CFU/100 mL, indicates microbiological contamination. Water in Chattogram is unsafe for drinking without appropriate disinfection and iron removal treatment.

Table 5. Average Water Quality Parameters Compared with ECR 2023 Standards

Parameters	Gazipur	Chandpur	Savar	Chattogram	BD Standard	Remarks
<b>pH</b>	7.3	7.4	7.8	7.4	6.5-8.5	ECR 2023
<b>TDS (mg/l)</b>	135.5	283	76.5	310	1000	
<b>Turbidity (Ntu)</b>	1.56	0.84	0.35	0.96	5	
<b>Iron (mg/l)</b>	1.01	1.51	1.54	1.49	0.3-1.0	
<b>Arsenic (mg/l)</b>	0.004	0.02	0.004	0.00	0.05	
<b>Nitrate (mg/l)</b>	0.65	0.22	0.22	0.443	45	
<b>Chloride (mg/l)</b>	35	65	30	210	250	
<b>Hardness (mg/l)</b>	147	304.9	84	127.5	500	
<b>Fecal Coliform(CFU/100ml)</b>	3	9	6	25	0	

Table 6 shows the WQI values for the sampling sites. Gazipur and Chattogram have WQI scores between 51 and 75, which means the water quality is poor. WQI in Chandpur & Savar also ranges between 76 and 100, which indicates the water quality in these areas is very poor and unsafe without treatment. The average WQI also lies within the poor water quality, which shows major health concerns by consuming the groundwater of these areas. Figure 2 illustrates the Water Quality Index (WQI) for four sampling locations. Different colors are used to represent the water quality status, where orange indicates poor water quality and red indicates very poor water quality.

Table 6. Water Quality Index (WQI) Classification for the Study Locations

Location	WQI value	Category range	Water quality class
Gazipur	54.52	51–75	Poor
Chandpur	79.58	76–100	Very Poor
Savar	79.34	76–100	Very Poor
Chattogram	70.22	51–75	Poor
Avg.	70.92	51–75	Poor

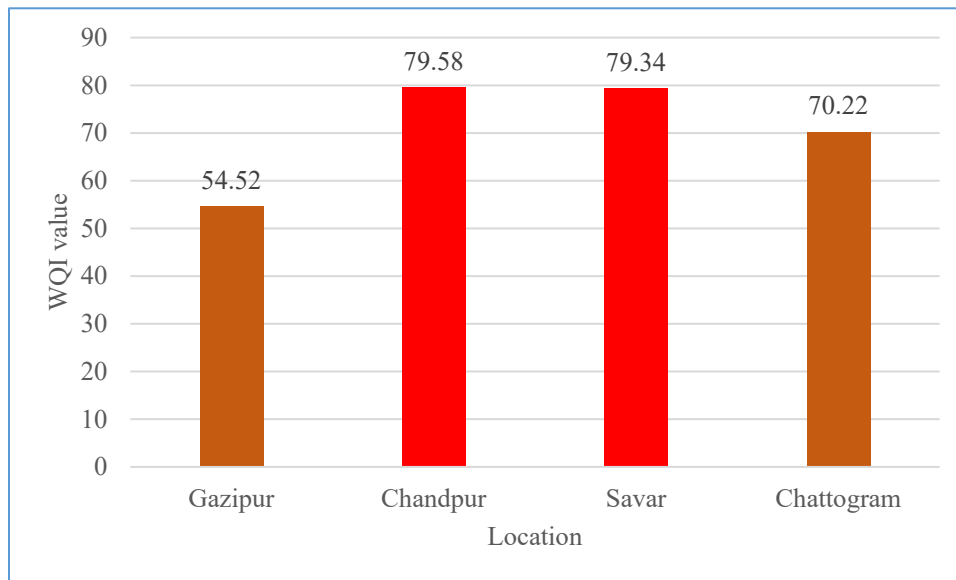


Figure 2. Water Quality Index (WQI) of Different Sampling Locations

## 6. Conclusion

The assessment of groundwater quality in Gazipur, Chandpur, Savar, and Chattogram revealed noticeable spatial variations in physicochemical parameters when compared to the Bangladesh ECR 2023 drinking water standards. The values of pH, TDS, turbidity, nitrate, and chloride were mostly within the acceptable range, indicating good groundwater quality overall. However, the concentrations of iron and fecal coliform were consistently higher than the allowable limits in every location, which makes the water unsafe for direct human consumption. Elevated iron levels can cause aesthetic, taste, and staining problems, while fecal coliform contamination poses serious health risks, indicating possible intrusion of wastewater or poor sanitation practices near tube wells. The WQI results show that Chandpur and Savar have very poor groundwater quality, while Gazipur and Chattogram fall into the poor category. This means all sites require treatment before the water is safe for drinking. Despite some parameters meeting national standards, elevated iron and widespread fecal contamination significantly lower overall quality. Improving water treatment, sanitation practices, and routine monitoring is essential to ensure safe drinking water in these areas.

## 7. Future Work

Based on the findings of this research, the following future studies can be recommended to best understand the groundwater:

- i. The number of sampling locations should be expanded to cover more districts and aquifer types across Bangladesh.
- ii. Seasonal monitoring may be introduced to understand how water quality changes between dry and monsoon periods.
- iii. Additional water quality parameters such as heavy metals (Pb, Cd, Cr, Mn, As) could be tested.
- iv. A GIS-based groundwater quality map may be developed for better visualization of contamination hotspots.
- v. Machine learning or hydrogeochemical modeling may be developed to forecast future groundwater contamination trends.
- vi. Shallow and deep tube wells can be compared to determine safe aquifer depths for drinking water extraction.

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