Water Quality Assessment in Terms of Water Quality Index (WQI) Using GIS in Ballia District, Uttar Pradesh, India

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Abstract

In the present study, water quality of groundwater has been assessed in terms of water quality index (WQI) in Ballia district of Uttar Pradesh. Data of 12 groundwater samples each of hand pump and bore well was taken for computing the Water Quality Index using eleven parameters viz. pH, Total Dissolved Solids, Turbidity, Total Hardness, Arsenic, Fluoride, Chloride, Nitrate, Iron, Sulphate and Dissolved Oxygen. The WQI results show that the overall water quality class is 'fair' and water needs treatment.

Keywords: Water quality index; Groundwater; Ballia; Uttar Pradesh; Gangetic plains

Introduction

Groundwater is the largest fresh water resource on the mother earth and quality of groundwater is influenced by the natural/geogenic and/or anthropogenic sources. Regular monitoring of groundwater quality is essential as it becomes extremely difficult to restore the contaminated groundwater. Water Quality Index (WQI) is an easy and important tool to assess spatial and temporal changes in ground water quality and has been used by various researchers [1-11].

In recent years, excessive use of groundwater has led to its depletion and deterioration of quality in Gangetic basin [12-27] and water quality evaluations have been carried out other parts of India as well [28-36].

Ballia district, the eastern most part of Uttar Pradesh and a part of Central Ganga Plains, occupies an irregular wedge shape tract in interfluval region of rivers Ganga and Ghaghara. The district has geomorphic units flood plain, newer and older alluvial plains and depth to water level is up to 550 m in shallow, intermediate and deep aquifers. Groundwater occurs in unconfined, semi-confined and confined aquifers with the presence of arsenic, fluoride and iron more than the permissible limits [37]. Therefore, there is an urgent need to assess the groundwater quality for drinking purpose. In the present study, groundwater quality is assessed for drinking purpose in terms of WQI in Ballia district, Uttar Pradesh.

Study Area

Ballia district with a total geographical area of 2981 km², lies between latitude 25°23’ N-26°11’N and longitude 83°38”-84°39”E (Figure 1). The district has geomorphic units flood plain, newer and older alluvial plains and depth to water level is up to 550 m in shallow, intermediate and deep aquifers. Groundwater occurs in unconfined, semi-confined and confined aquifers with the presence of arsenic, fluoride and iron more than the permissible limits [37]. Therefore, there is an urgent need to assess the groundwater quality for drinking purpose. In the present study, groundwater quality is assessed for drinking purpose in terms of WQI in Ballia district, Uttar Pradesh.

Methodology

The Water Quality Index (WQI) was computed using 11 water quality parameters viz. pH, Total Dissolved Solids, Turbidity, Total Hardness, Arsenic, Fluoride, Chloride, Nitrate, Iron, Sulphate and Dissolved Oxygen of 12 groundwater samples of hand pump and bore hole each (Figure 2) given by Srivastava [38]. As reported by Srivastava [38], water samples have been collected from hand pumps and bore wells after cleaning the bottle with 6M HNO₃, which is followed by washing with double distilled water. The samples were analysed by standard methodology [39]. The methods reported by Singh et al. [7] have been employed where quality rating scale was used assigning the weight values to the selected parameters (Table 1) and have been classified into 5 categories (Table 2).

Geographic information system (GIS) is most effective tool to provide better information for the consumers, policy makers and this helps for taking quick decision. For representing the spatial distribution of sampling locations, the coordinates have been found using the Google Earth satellite view. The interpolation of the water sample values has been done by Inverse Distance Weighting (IDW) interpolation technique in the ArcGIS 9.3 software.

Results and Discussion

The statistical summary of physico-chemical parameters and WQI variation of 12 samples each taken from hand pump and bore well

| S No | Parameter          | Weight Factor | Standards (BIS-10500) (1991) |
|------|--------------------|---------------|-------------------------------|
| 1    | pH                 | 1             | 6.5-8.5                       |
| 2    | Total Dissolved Solids (mg/l) | 3     | 500-2000                     |
| 3    | Total Hardness (mg/l) | 1           | 300-600                      |
| 4    | Turbidity          | 1             | <5                            |
| 5    | DO                 | 4             | >8                            |
| 6    | Fluoride           | 3             | <1.5                          |
| 7    | Chloride (mg/l)    | 1             | 250-1000                     |
| 8    | Sulphate (mg/l)    | 2             | 25-1000                       |
| 9    | Nitrate            | 3             | <45                           |
| 10   | Iron               | 3             | <0.3                          |
| 11   | Arsenic            | 4             | <0.05                         |

Table 1: Significance weight and water quality parameters [7,35,44].

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Figure 1: Location map of the study area.

Figure 2: Map showing sampling locations in Ballia District, Uttar Pradesh.
in Ballia district, Uttar Pradesh is given in Table 3. The Hydrogen-ion concentration (pH) values are one of the important factors of groundwater and in present study, the value of pH is found lower than the desired limit (8.5) prescribed by BIS in all the samples.

Total dissolved solids (TDS) in all the samples taken from hand pump varies from 425 to 2856 mg/l while in the samples taken from bore well, TDS varies from 451 to 1253 mg/l (Table 3). The higher values of TDS are attributed to application of agricultural fertilizer contributing the higher concentration of ions into the groundwater [40].

Total hardness of water is a measure of dissolved Ca and Mg and is expressed as (CaCO₃) [41] and in the samples taken from hand pump it varies from 211 to 960 mg/l the samples taken from bore well it varies from 462 to 2230 mg/l. Accordingly, the groundwater quality in study area is classified as hard water. The turbidity value varies from 1 to 7 NTU with an average value of 4 and 2 to 9 NTU with an average value of 5 in hand pumps and bore wells water, respectively.

Fluorides concentration in groundwater is found to exceed the permissible limit of 1.5 mg/l in most of the samples and the main sources of fluoride are geogenic/natural like minerals, rocks and sediments. The spatial distribution of fluoride is shown in Figure 3, which indicates fluoride concentration is evenly distributed in whole district. The chloride content in most of the samples taken from hand pump and few samples from bore well have high chloride concentration and some much higher the permissible limit of 200 mg/l. This may be due to its wide distribution in natural environment. The average nitrate value is observed 2.0 mg/l and 1.9 mg/l, in the samples taken from hand pump and bore well, respectively which is well within the permissible limit of 45 mg/l.

The average concentrations of iron is found 2.09 mg/l and 1.04 mg/l in the samples taken from hand pump and bore well, respectively exceeding the desirable limit of 0.3 mg/l [42]. Excess iron in water is mostly accumulated through the weathering of rocks and industrial effluents discharge. The average concentrations of arsenic found 0.17 mg/l and 0.18 mg/l in the samples taken from hand pump and bore well, respectively exceeding the desirable limit of 0.05 mg/l. The spatial distribution of arsenics is shown in Figure 4, which indicates arsenic concentration is evenly distributed in the whole district. The higher arsenic contents may be of geogenic origins in underground alluvial formations.

Dissolved oxygen DO reflects the water quality status of physical and biological processes in water and shows the metabolic balance. DO Levels act as an indicator of status of the water body. The DO average value varies from 11.78 to 21.12 mg/Land from 15.42 to 26.18 mg/L in hand pump and bore well water, respectively. According to the data by Srivastava [38], the DO values are surprisingly high and these need further investigation.

The computed WQI values and their spatial distribution for 12 bore wells and 12 hand pumps each in Ballia district, Uttar Pradesh range from 66 to 74 and from 62 to 79, respectively as shown in Figure 5 and can be categorized into “fair” type. The water needs ‘Filtration and disinfection’ treatment. The reason of low values of WQI may be the higher values of TDS, total hardness, As, F, Cl, HCO₃⁻, NO₃⁻ and SO₄²⁻.

| Class           | WQI Value | Status of Water                  |
|-----------------|-----------|----------------------------------|
| Heavily Polluted| 0–24      | Unsuitable for All Purposes       |
| Poor            | 25–49     | Special Treatment                |
| Fair            | 50–74     | Needs Treatment (Filtration and Disinfection) |
| Good            | 75–94     | Acceptable                       |
| Excellent       | 95–100    | Pristine Quality                 |

Table 2: WQI and corresponding class and status of water quality [7-11].

Figure 3: Spatial variation of fluoride in groundwater samples (handpump and borewells) of Ballia District, Uttar Pradesh.
### Table 3: Physico-chemical parameters and WQI of groundwater samples in Ballia District, Uttar Pradesh

| Parameters | pH | Turbidity TU | mg/l | WQI |
|------------|----|--------------|------|-----|
|            |    |              |      |     |
| **Hand pump (n=12)** | | | | |
| Minimum    | 7.16 | 1 | 12 | 425 | 0.06 | 1.12 | 1.3 | 114.0 | 0.8 | 12.7 | 211 | 66 |
| Maximum    | 7.94 | 7 | 21 | 2856 | 0.28 | 2.96 | 2.7 | 535.3 | 2.8 | 34.5 | 960 | 74 |
| Average    | 7.45 | 4 | 16 | 1040 | 0.17 | 2.09 | 1.9 | 258.3 | 2.0 | 20.8 | 578 | 69 |
| Std. Deviation | 0.28 | 2 | 3 | 666 | 0.06 | 0.59 | 0.4 | 134.2 | 0.6 | 6.70 | 137 | 3 |

| **Bore well (n=12)** | | | | |
| Minimum    | 6.48 | 2 | 15 | 451 | 0.07 | 0.12 | 1.5 | 120.0 | 0.7 | 10.2 | 462 | 62 |
| Maximum    | 8.02 | 9 | 26 | 1253 | 0.32 | 2.15 | 2.6 | 245.0 | 3.9 | 38.6 | 2230 | 79 |
| Average    | 7.47 | 5 | 21 | 864 | 0.18 | 1.04 | 2.4 | 175.3 | 1.9 | 20.7 | 1359 | 67 |
| Std. Deviation | 0.45 | 2 | 3 | 289 | 0.08 | 0.58 | 0.4 | 40.6 | 1.0 | 11.6 | 441 | 5 |

**Figure 4:** Spatial variation of arsenic in groundwater samples (handpump and borewells) of Ballia District, Uttar Pradesh.

**Figure 5:** Spatial variation of water quality index in groundwater samples (hand pump and borewells) in Ballia District, Uttar Pradesh.
Ballia district, Uttar Pradesh. The WQI show that overall groundwater samples in Ballia district, UP qualify in the 'Fair' category and are not fit as such for drinking. The water needs ' Filtration and disinfection ' treatment and then can be used for the drinking purpose. The reason of low values of WQI may be the higher values of TDS, Total Hardness, As, F, Cl, HCO3, NO3, and SO4. Continuous monitoring of groundwater is required by establishing a planned monitoring network in the study area for regular assessment of the WQI which will be useful in proper management of the water resources.

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