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Groundwater quality assessment using water quality indices: a case study of bore wells in Ratu Block, Ranchi

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ABSTRACT

Groundwater is a vital resource for drinking, irrigation, and industrial use. However, rapid industrial growth and waste discharge have raised serious concerns about groundwater pollution. This study evaluates the groundwater quality of bore wells in Ratu Block, Ranchi, using Water Quality Indices (WQIs). Water samples were collected from 18 bore wells across 10 villages and analyzed for key physico-chemical parameters, including pH, total dissolved solids (TDS), total alkalinity, and total hardness. The Indian Standard Drinking Water Specification (IS 10500: 2012) was used to assess water quality. The results indicate that most bore wells have WQI values ranging from 120 to 250, with some exceeding 300, categorizing them as "Poor" to "Unsuitable for Drinking." Recommended measures such as disinfection and hardness removal treatments are necessary. Regular groundwater monitoring and treatment are recommended to ensure safe drinking water

Key Words - Bore wells, Groundwater, Water Quality Indices, pH, total dissolved solids, total alkalinity.

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INTRODUCTION

Groundwater is a vital resource for drinking, irrigation, and industrial use. However, its quality is influenced by natural and anthropogenic factors, necessitating regular assessment to ensure its safety and suitability. One effective method for evaluating groundwater quality is through Water Quality Indices (WQIs), which consolidate various physico-chemical parameters into a single value representing overall water quality. According to recent studies, the fast population growth and the accelerated rate of industrialization over the past few decades have increased the need for freshwater. (Zhang, 2017) More than half of the world's population now depends on ground water for sustenance, and this demand has led to the usage of ground water due to its widespread occurrence and availability as well as its constant high quality, which makes it an ideal supply of drinking water. However, the widespread expansion of industry has raised significant worries about the potential for groundwater pollution from waste material disposal. (Bharti and Katyal, 2011).

Given the significance of groundwater in sustaining human and ecological well-being, it is essential to conduct regular assessments to ensure its safety and suitability for consumption and other uses. WQIs simplify complex datasets, making it easier for policymakers, environmental agencies, and researchers to interpret and communicate water quality information effectively. This approach facilitates timely interventions to mitigate contamination and promote sustainable water resource management. Numerous social and economic factors, including human activity, climate change, and hydrology, can cause contaminants to build up in surface water, which could eventually alter the quality of the water supply (Shan, 2011).

As was previously noted, maintaining an appropriate level of water quality is a challenge in the field of water resources management, despite the fact that having an enough amount of water is one of the necessities for survival. Accordingly, alterations in physical, chemical, and biological traits associated with man-made or natural events can be used to test the water quality of bodies of water. (Mukate *et al.*, 2019). There isn't a single, widely recognised WQI. Therefore, it is essential to evaluate the different Water Quality Indices and create the most appropriate WQI that can be applied broadly. The purpose of this effort is to evaluate the water quality of bore wells. This article aims to characterise the water quality of bore wells using various water quality indicators and to identify conclusions based on these indicators.

MATERIALS & METHODS

Sample Collection and Analysis

Groundwater samples were collected from 10 different randomly selected locations, viz. Hurhuri, Hehal, Hochar, Gutuatoli, Ekaguri, Chitarkota, Hisri, Kantu, Mariatu and Murgu. They were stored in sterile bottles, and analyzed for various physico-chemical parameters using standard methods such as APHA (American Public Health Association) procedures. For the investigation, the grab sampling method was used. Water is collected and stored using plastic containers. Every sample is kept in containers with a one-litre capacity. The container is twice cleaned using water from the appropriate sampling site. After usage, the container is cleaned three times with tap water and once with mild acid. The winter season is the time for sampling, which lasts from 4 to 7 p.m. Samples were examined for physico-chemical and bacteriological characteristics using conventional procedures.

Data Processing and Calculation of WQI

Each parameter is compared with standard permissible limits. A quality rating scale is assigned to each parameter based on its concentration. Weightage factors are determined for different parameters based on their significance in water quality assessment. The overall WQI is calculated using specific mathematical formulas associated with the selected index method.

Interpretation and Categorization

Numerous scientists have utilised the weighted arithmetic water quality index approach extensively to calculate WQI. During the current study also, this method was used to calculate WQI.

$$WQI = QiWi/Wi$$

Based on WQI values, groundwater quality is categorized as:

Excellent (WQI < 50)

Good (WQI 50-100)

Poor (WQI 100-200)

Very Poor (WQI 200-300)

Unsuitable for Drinking (>300)

RESULT & DISCUSSION

The physicochemical analysis of groundwater samples collected from eighteen bore wells across ten villages of Ratu Block reveals considerable spatial variation in water quality (Table 1 & 2). The assessment was carried out using key parameters such as pH, total alkalinity, total dissolved solids (TDS), and total hardness, which are critical indicators of groundwater suitability for drinking purposes.

pH values across all bore wells ranged from 6.85 to 8.20, remaining within the permissible limits prescribed by IS 10500:2012. This indicates that the groundwater is generally neutral to slightly alkaline in nature, suggesting adequate buffering capacity. Minor fluctuations observed among sampling sites may be attributed to differences in local geology and groundwater recharge conditions. The acceptable pH values indicate that acidity or alkalinity alone is not a major limiting factor for groundwater use in the study area.

Total alkalinity showed marked variation among sampling locations, with values ranging from 100 mg/L at Ekaguri (B2) to as high as 450 mg/L at Bijuliya (B5). Several bore wells recorded alkalinity values exceeding the desirable limit, reflecting the presence of bicarbonates and carbonates in groundwater. Elevated alkalinity may result from prolonged water-rock interaction and dissolution of carbonate-rich minerals. High alkalinity can impart an unpleasant taste to drinking water and may also interfere with disinfection processes.

Total dissolved solids (TDS) concentrations varied widely, ranging from 508 mg/L (B7, Kathitad) to 1860 mg/L (B1, Belangi). Although all values remained within the maximum permissible limit, many bore wells exceeded the desirable limit of 500 mg/L. Particularly high TDS levels were recorded in Belangi, Simalia, Makhmandro, and Brajpura villages, indicating increased mineralization of groundwater. Elevated TDS levels are often associated with geological formations, leaching of salts, and anthropogenic influences such as domestic wastewater seepage. High TDS can affect water palatability and may pose long-term health risks if consumed continuously.

Total hardness values ranged from 250 mg/L to 750 mg/L, with several bore wells exceeding the acceptable limit of 600 mg/L. The highest hardness was observed at Murgu (B17), while comparatively lower values were recorded at Makhmandro (B10). Elevated hardness is mainly attributed to the presence of calcium and magnesium salts, likely derived from limestone and dolomite formations in the region. Hard water can cause scaling in pipes and appliances and may also be associated with health concerns such as kidney stone formation.

Table 1- Showing WQI Values & Classification

Parameter	Range	Permissible Limit (IS 10500: 2012)
pH	6.5–8.2	6.5–8.5
TDS (mg/L)	508–1860	500–2000
Hardness (mg/L)	250–750	200–600
Alkalinity (mg/L)	100–450	200–600

Table 2 - Showing the characterization of water sample

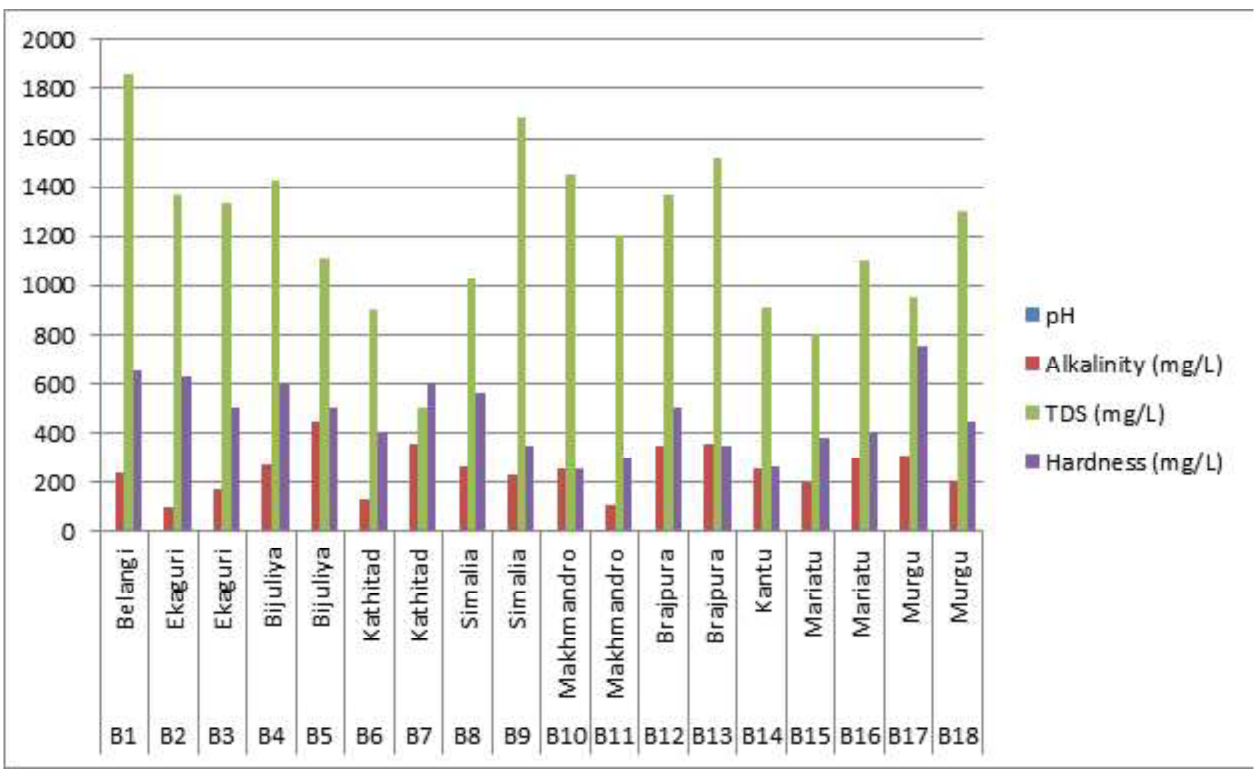
Sl. No.	Bore wells sampling no.	Villages of Ratu block	pH	Alkalinity (mg/L)	TDS (mg/L)	Hardness (mg/L)
1.	B1	Belangi	7.01	239	1860	652
2.	B2	Ekaguri	6.95	100	1365	630
3.	B3	Ekaguri	7.11	169	1336	508
4.	B4	Bijuliya	7.03	270	1426	602
5.	B5	Bijuliya	8.1	450	1112	506
6.	B6	Kathitad	6.98	135	903	403
7.	B7	Kathitad	7.02	356	508	603
8.	B8	Simalia	6.85	265	1025	565
9.	B9	Simalia	7.1	234	1685	350
10.	B10	Makhmandro	7.05	258	1450	258
11.	B11	Makhmandro	6.89	109	1200	294
12.	B12	Brajpura	8.2	350	1364	502
13.	B13	Brajpura	7.09	357	1520	345
14.	B14	Kantu	6.98	256	909	265
15.	B15	Mariatu	6.9	198	803	378
16.	B16	Mariatu	7.06	301	1102	409
17.	B17	Murgu	7.04	309	956	750
18.	B18	Murgu	7.02	208	1302	443
19.	**Acceptable limit**		6.5–8.5	200–600	500–2000	200–600

When these parameters were integrated using the weighted arithmetic Water Quality Index method, the resulting WQI values ranged from 120 to above 300, categorizing most bore wells as Poor to Very Poor, with a few falling under the Unsuitable for Drinking category. Bore wells with high TDS and hardness contributed significantly to elevated WQI values, indicating that these parameters play a dominant role in deteriorating groundwater quality in the area.

The spatial distribution of poor groundwater quality suggests that localized hydrogeological conditions and increasing anthropogenic pressure, including urban expansion and improper waste disposal, are influencing groundwater chemistry. The findings align with earlier studies that reported groundwater quality deterioration in rapidly developing regions.

Overall, the table-based results clearly demonstrate that although pH remains within acceptable limits, elevated alkalinity, TDS, and hardness are major factors contributing to poor groundwater quality in Ratu Block. These findings highlight the urgent need for appropriate water treatment measures, such as softening and filtration, along with regular groundwater monitoring to ensure safe drinking water availability.

Kareem *et al.* (2021) tried to assess the water quality of the Euphrates River (Iraq) for irrigation purposes in three separate stations: WAWQI, CCMEWQI, and OWQI, using three water quality indices. A study was carried out in Mexico at the Luis L. Leon dam by Rubio-Arias *et al.* (2012). Samples were taken every month at ten random locations along the dam at varying depths; 220 samples in all were taken and examined. The Weighted WQI equation was used to calculate the WQI, which was categorised into three ranges: <2.3 poor, 2.3 to 2.8 decent, and >2.8 excellent. Eleven parameters were taken into consideration.



Graph 1 :- Graphical representation of the characterization of water sample

CONCLUSION

The study's findings underscore the pressing concern of groundwater contamination in the Ratu Block area. The majority of bore wells examined were found to be unfit for human consumption, primarily due to elevated hardness, TDS, and in some cases, bacterial contamination. Based on the WQI classification, most bore wells were categorized as "Poor" to "Very Poor," with some wells deemed "Unsuitable for Drinking." These results indicate the need for immediate interventions to improve water quality. To ensure the safety of the water for human consumption, measures such as disinfection and hardness removal treatments are urgently required. The findings also emphasize the importance of monitoring groundwater quality regularly, particularly in areas undergoing rapid industrialization and population growth.

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