GEO-EYE

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Comparative Spatial Analysis of Groundwater Quality in Rural and Urban Areas of Ramgarh District, Jharkhand Using Hydrochemical Parameters

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Abstract

Groundwater is a crucial source of freshwater for drinking and irrigation, particularly in rural and semi-urban regions of developing countries. Rapid urbanization, population growth, and anthropogenic activities increasingly threaten groundwater quality. This study evaluates the spatial variation of groundwater quality across rural and urban areas of Ramgarh District, Jharkhand, India. A total of 51 groundwater samples were collected from wells, hand pumps, and tube wells across six administrative blocks during the post-monsoon period of December 2025. Key hydrochemical parameters including pH, Total Dissolved Solids (TDS), and Electrical Conductivity (EC) were analysed and compared with World Health Organization (WHO) and Bureau of Indian Standards (BIS) guidelines. The results indicate that pH values in both rural and urban areas remain within permissible limits, suggesting neutral groundwater conditions. However, urban areas exhibit higher TDS and EC values compared to rural areas, indicating greater mineralization and potential anthropogenic influence. The spatial maps produced in this study provide a useful baseline for monitoring groundwater quality and identifying safe and vulnerable zones for future water resource management in the district.

Keywords: Groundwater Quality; Rural–Urban Comparison; Hydrochemical Parameters; Spatial Analysis; Ramgarh District

1 Introduction

The world's greatest freshwater supply for rural and semi-urban people, groundwater is the purest natural water source and serves as a risk buffer during dry spells[39]. In these geographic areas, groundwater is essential for drinking supplies. According to UNESCO (2015), one-third of the world's population now solely relies on groundwater[61]. Groundwater is the water that permeates every void in a geological stratum. Water makes up the majority of the earth's crust, which acts as a reservoir and a conduit for information[21]. As the need for high-quality water in homes, businesses, and agriculture has grown, groundwater is favored because of its wider spread and lesser contamination[12]. Surface water and precipitation provide groundwater with replenishment. The natural replenishment that comes from streams and other natural water sources, the man-made recharge process, and the water that falls on the earth naturally as a result of precipitation are all examples[2]. Due to the severe groundwater scarcity in Indian regions, many research have been conducted to find possible areas. Global models that combine remote sensing technology and GIS are being created[14]. India's 60-65 million inhabitants are consuming contaminated groundwater, causing harm to 3 million people, primarily in Rajasthan, Punjab, Gujarat, Madhya Pradesh, Uttar Pradesh, Jharkhand, Andhra Pradesh, and Tamilnadu[56]. Remote sensing technology effectively collects vast data on groundwater's movement, migration, and recharge, providing micro-level insights into various characteristics[1]. Groundwater potential zone mapping is made easier with RS and GIS, which are dependable, economical, and time-efficient methods for water management and conservation[13].

The greatest freshwater supply in the world, groundwater is the purest natural resource and provides rural and semi-urban communities with a buffer against risk during dry spells[40]. In these geographic areas, groundwater is essential for drinking supplies. Currently, a third of the world's population is solely dependent on groundwater[61]. The earth's crust contains the majority of groundwater, a type of water that permeates all geological layers and serves as a reservoir and a conduit for transmission[21]. As the need for high-quality water in homes, businesses, and agriculture has grown, groundwater is favored because of its wider spread and lesser contamination[12]. Precipitation, surface water from both natural and artificial sources, and man-made recharge mechanisms all contribute to the replenishment of groundwater[2]. Remote sensing data and GIS exploration help with resource evaluation and conservation by addressing groundwater management issues brought on by urbanization, population increase, climate change, and erratic rainfall[10].

As it indicates the salinity hazard to crops, measuring electrical conductivity is an excellent way to evaluate water quality for irrigation[32, 53].

Groundwater quality differs from place to place and this may therefore affect its suitability for consumption[60], For example, land-use has been found to affect the quality of groundwater[44, 60]. Polluted groundwater resource may initiate water-borne diseases such as gastroenteritis, cholera, typhoid fever and giardiasis[60].

Flow and transport processes affecting urban groundwater are not essentially different from those affecting groundwater in rural contexts, but the time and space scales involved are significantly different[29].

Urban groundwater systems are under increasing stress from rapid, unplanned urbanization, with contamination arising from industrial effluents, poor sanitation, agricultural runoff, and improper waste disposal[57]. Rapid, often unplanned urbanization has led to significant groundwater degradation driven by industrial discharges, leachate from urban solid waste dumps, and infiltration of domestic wastewater[38, 57]. Urbanization is a human-induced process that changes land use and land cover (LULC), as well as the amount and quality of surface and groundwater resources, particularly in urban and peri-urban areas[31, 35, 43]. The uneven distribution of water across time (temporal) and space (spatial) as well as the increased consumption and usage along with the problems of pollution, contamination, misuse and wastage; have given rise to water crisis in different parts of the world[15]. Surface waters are the best sinks for several point and non-point sources of pollution such as wastewater from agricultural and industrial processes, storm runoff amongst others[16, 42, 45]. The assessment frameworks presented can be applied to aquifer-wide monitoring and health risk assessment in other arsenic-affected urban and rural regions[9, 20, 40, 52]. The increasing population density, urbanization, and industrialization are driving forces to exceed groundwater extraction over recharge, decrease in water level and degradation of groundwater quality[46, 54].While groundwater is traded in some regions of the world, it is also widely used as a supply of water for home, industrial, agricultural, and energy generation operations[11, 26, 47-49, 65]. Sustainable groundwater development is not only constrained by resource availability but also by quality deterioration[24]. Whether it be through an increase in food production, a rise in farmers' incomes or the creation of jobs in the farm sector and other associated sectors, irrigation improves the economic situation of rural households[19].

Groundwater has become indispensable for sustaining agriculture under such conditions. It serves as a buffer during dry periods, supports crop production when surface water is restricted, and contributes to stabilizing rural livelihoods[4].

The main source water supply in most developing economies is groundwater from shallow wells[22, 23, 33, 37, 55]. Research assesses the physicochemical features and heavy metal concentrations in the Ranchi district in Jharkhand state, India, and represents the groundwater quality via different pollution indices[34].

Despite the growing importance of groundwater studies in Jharkhand, limited research has examined spatial differences between rural and urban groundwater quality in Ramgarh district using field-based hydrochemical parameters.

Objectives:

- To evaluate spatial patterns across rural and urban spaces in groundwater quality using key hydrochemical parameters
- To assess suitability for drinking and irrigation as per WHO and BIS standards.
- To identify the main natural and anthropogenic factors controlling spatial variability in groundwater quantity and quality.

Study Area:

Ramgarh district is located in the North eastern part of the state of Jharkhand. Ramgarh district covers an area of approximately 1341 km^2. This district is the centre of the Tri-important districts of Jharkhand namely Ranchi, Hazaribagh, and Bokaro. This proximity facilitates economic and social interaction which provides a cause to investigate groundwater standards as in recent times groundwater is a major resource and more recently a highly exploited resource. A study of Ramgarh district will allow to serve as a base for further studies.

Topography: The water table in topographic highs is usually deep, whereas in topographic lows it is shallow. This means that on topographic highs there is sufficient space for the water table to change. This space is lacking in topographic lows where the water table is often close to the surface[28]. Topography and climate are important controls on runoff response distribution (RRD) peak height, with topographic slope and the aridity index being the most influential factors[17]. Groundwater occurrence is influenced by the climate, physiography, drainage and geology of the area[36]. The influence of topography on the global terrestrial water cycle, from the atmosphere down to the groundwater[25]. Topography affects the distribution of water on Earth, often in surprising or extreme ways[25]. Distributions of water table depth often mirror surface topography. High up in the landscape, water tables tend to be deep, while at low elevations where water converges, water tables tend to be shallow[25]. Quartz vein and dolerite dyke act as a barrier for the movement of groundwater[18, 50]. Geospatial technologies are essential for groundwater potential assessment and evaluation considering significant controlling factors such as geology and topography[30, 41, 59].

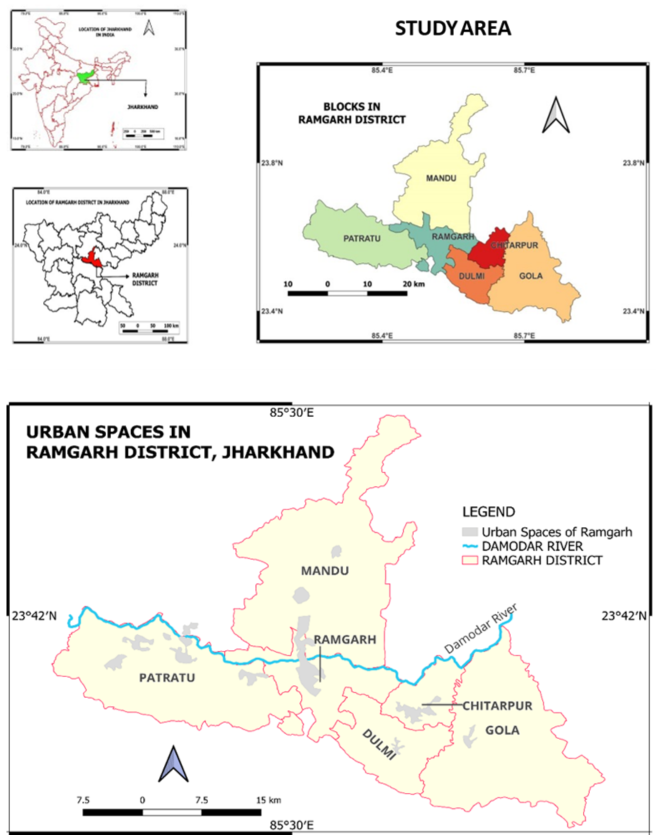

Fig. 1: Study area Maps showing the location of Ramgarh District and its Rural and Urban spaces

2 Methodology

Data Collection

Sample collection: The samples were collected from the selected area via tube wells, hand pumps and wells.

Sampling locations utilizing a GPS and thus as others. A total of 51 groundwater samples were collected, including 25 rural wells, 25 urban wells, and 1 well from a mining area in Mandu block as a case study., including field-measured pH, TDS, EC, well depth, elevation, GPS coordinates, and site photographs. Wells were selected using a stratified sampling approach to ensure representation across all six administrative blocks during the post monsoonal month of December 2025.

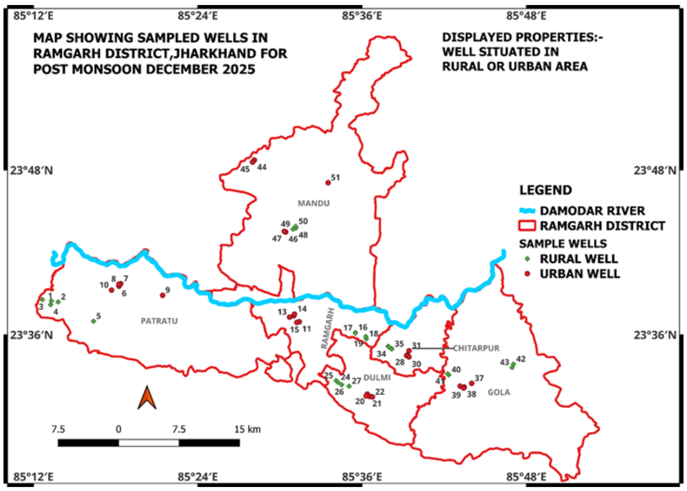

Fig. 2: Map showing the Sampled wells and if they are in rural or urban area

Laboratory Analysis: Electrical Conductivity (EC) was derived from Total Dissolved Solids (TDS) using standard conversion methods using the multiple 0.64. A Konvio water testing kit was use to obtain the values.

Statistical Analysis: Mean of values for each block and were performed to evaluate groundwater quality parameters. The analytical findings derived from the subsurface water samples are compared with the designated thresholds outlined in the WHO regulations governing drinking water.

3 Results and discussion

Overall, the finding can be visualised as given in [Table. 1].

The data is better elaborated as follows with each parameter explained and interpreted separately and thereafter compared to global (WHO) and Indian (BIS) standards.

Table 1: Comparison of average groundwater quality parameters in rural and urban areas of Ramgarh district with WHO and BIS drinking water standards

Parameter	WHO Limit	BIS Limit	Urban Average	Rural Average	Interpretation
pH	6.5-9.5	6.5-8.5	7.01	7.02	Both rural and urban groundwater show neutral conditions and remain well within permissible limits.
TDS (mg/L)	1000	500 (desirable)	601.81	323.79	Urban groundwater shows higher mineral content and slightly exceeds BIS desirable limit, while rural water remains within safe limits.
EC (µS/cm)	1500	780 (desirable)	940.37	505.96	Urban areas exhibit higher ionic concentration indicating greater mineralization, whereas rural groundwater remains within acceptable limits.

pH:

The pH determines the acidity and alkalinity of groundwater as a significant water quality parameter. The permissible limit of pH ranged from 6.5 to 9.5 as per WHO recommendations and 6.5 to 8.5 according to BIS standards for drinking purposes. Average Urban pH 7.01, Average Rural pH 7.02.

The minimal variation between rural and urban values suggests that land-use differences have not significantly influenced groundwater acidity or alkalinity. Such stable pH conditions may be attributed to the buffering capacity of local geological formations and natural groundwater recharge processes.

TDS and EC:

Total dissolved solids (TDS): Total Dissolved solids comprise of organic matter and inorganic salts, which may originate from sources such as sewage, effluent discharge, urban run-off or from natural bicarbonates, chlorides, sulphate, nitrate, sodium, potassium, calcium and magnesium TDS indicate fully dissolved minerals, such as calcium, chlorides, carbonates, bicarbonates, magnesium, silica, and sodium, in groundwater. The higher TDS levels in urban areas suggest greater mineralization, possibly influenced by urban runoff, wastewater infiltration, and increased human activities

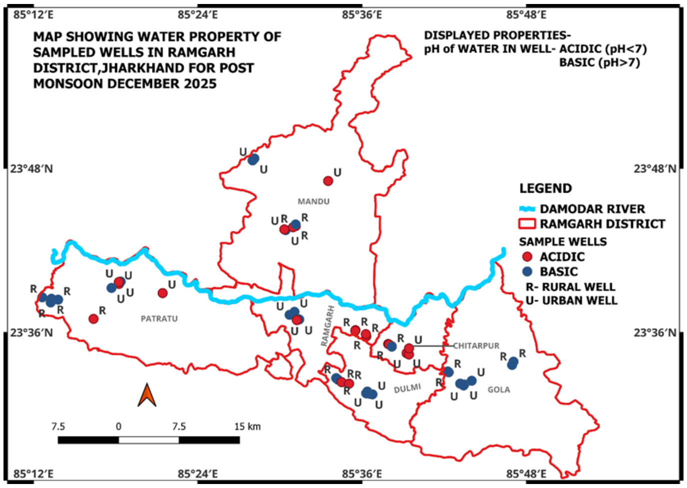

Fig. 3: Map showing the pH levels across the rural and urban areas in Ramgarh district

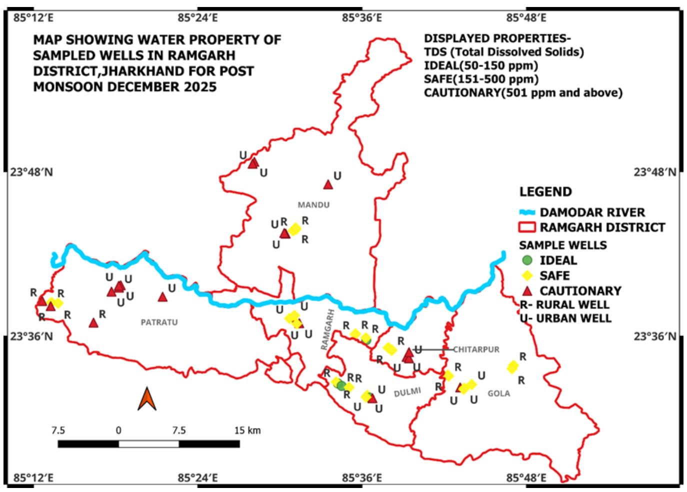

Fig. 4: Map showing the TDS levels across the rural and urban areas in Ramgarh district

Electrical conductivity (EC): Electrical conductivity is a measure of ion concentrations that depends on the temperature and type of ions and their concentrations in the water. EC is directly proportional to the dissolved material in a water sample. The desirable limit of EC for drinking purpose is 750 µS/cm. The comparatively higher EC in urban areas indicates greater dissolved ion concentration, which may be associated with urbanization, mining activity, and higher groundwater extraction in the district.

Table 2: Average Total Dissolved Solids (TDS) and Electrical Conductivity (EC) in Urban and Rural Groundwater Samples of Ramgarh District

Area	Average TDS (mg/L)	Average EC (µS/cm)
Urban	601.81	940.37
Rural	323.79	505.96

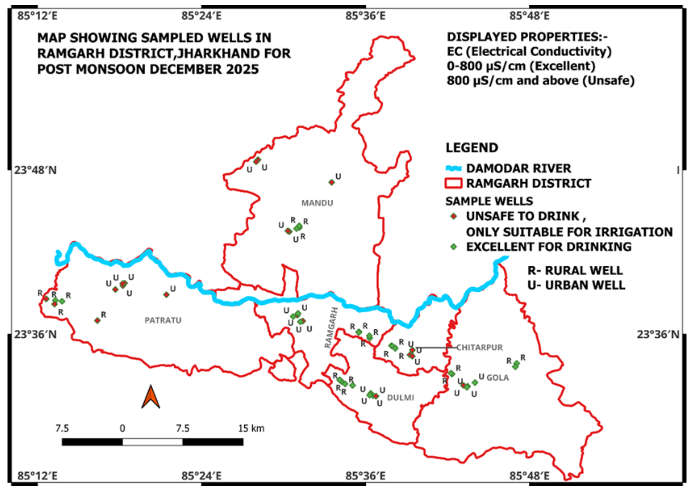

Fig. 5: Map showing the EC levels across the rural and urban areas in Ramgarh district

Comparison to WHO and BIS standards:

pH:

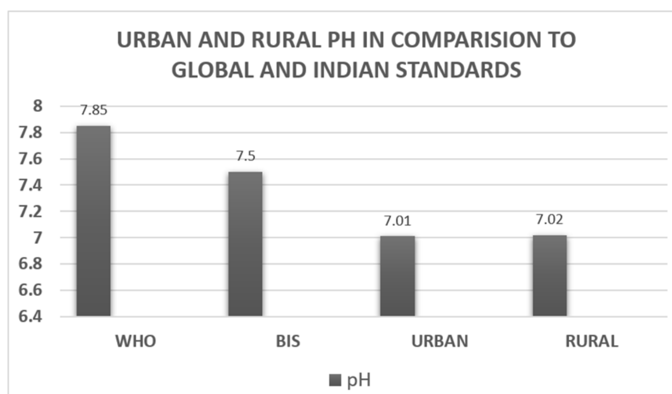

Fig. 6: Graph showing the average urban and rural pH in comparison to WHO and BIS standards

Comparison with international and national standards shows that pH levels in both rural and urban groundwater remain within safe limits. However, TDS and EC values are higher in urban areas, indicating moderate mineralization compared to rural groundwater. While the values remain within WHO permissible limits, the slight exceedance of BIS desirable limits in urban areas suggests growing anthropogenic influence on groundwater quality. The spatial maps produced in this study help identify relatively safer rural zones and comparatively stressed urban areas, providing a useful baseline for future groundwater monitoring and management.

TDS and EC:

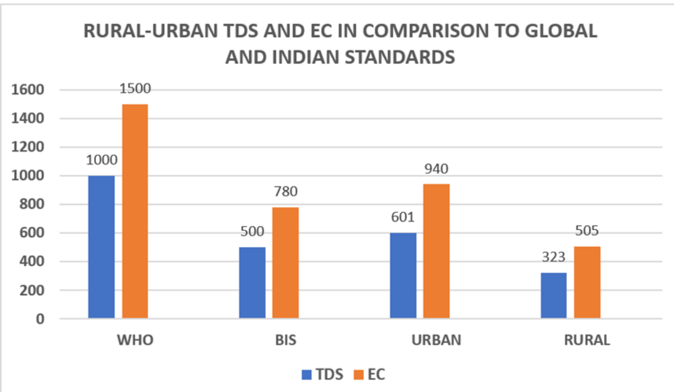

Fig. 7: Graph showing the average urban and rural TDS as well as EC in comparison to WHO and BIS standards

4 Conclusion

The present study assessed groundwater quality in rural and urban areas of Ramgarh district using key hydrochemical parameters including pH, Total Dissolved Solids (TDS), and Electrical Conductivity (EC). The results indicate that groundwater in both rural and urban areas remains neutral in pH and within the permissible limits of WHO and BIS standards, suggesting no immediate concern regarding acidity or alkalinity. However, urban groundwater shows comparatively higher TDS and EC values, reflecting greater mineralization likely influenced by urban activities, wastewater infiltration, and mining-related processes within the district. In contrast, rural groundwater appears relatively fresher and more suitable for drinking purposes.

The spatial distribution maps generated in this study provide a useful baseline reference for future groundwater monitoring and planning. Future research should focus on seasonal groundwater assessment, inclusion of additional physicochemical and heavy metal parameters, and long-term monitoring to evaluate temporal changes. Further studies may also incorporate water quality indices and geospatial modelling techniques to better understand the impact of urbanization and mining activities on groundwater sustainability in the region.

Photo Plate:

Fig. 8: A) Water Sample taken at Ramgarh Block office well; B) Konvio Kit used for TDS and EC; C) Water Sample and enquiry at rural pond; D) In discussion with a respondent running bottled water business using ground water in Patratu Urban space; E) A rural drinking water well; F) Sample testing by authors in St. Xavier's College Ranchi Laboratory

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