

## **Spatio-Temporal Patterns Of Groundwater Quality Based On Hydrochemical Indicators In Haryana’s Bhiwani And Hisar Districts**

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### **ABSTRACT**

Overexploitation of groundwater in Haryana's Bhiwani and Hisar districts has led to significant fluctuations in both quantity and quality, especially in unconfined aquifers. This study investigates the spatio-temporal distribution of groundwater quality using hydrochemical indicators such as pH, nitrate, fluoride, sulphate, magnesium, and electrical conductivity to understand the evolving status of groundwater resources. By integrating laboratory hydrochemical analysis with geospatial techniques, the research identifies vulnerable zones and tracks quality shifts between 2019 and 2023. The findings emphasize the need for comprehensive monitoring, sustainable management, and policy interventions to safeguard groundwater resources in semi-arid northern India.

**KEYWORDS:** Groundwater, Quality Parameters, Hydro Chemical, Bhiwani, Hisar

### **1. INTRODUCTION**

Groundwater is a critical resource supporting agriculture, industry, and domestic needs across the globe, and its significance is especially pronounced in arid and semi-arid regions. In India, groundwater serves as the primary water source for large populations, reflecting both the country’s heavy reliance on subterranean aquifers and the vulnerability of these reserves to anthropogenic stress. Bhiwani and Hisar districts of Haryana epitomize the challenges of groundwater management: rapid urbanization, population growth, and intensified agricultural activities have resulted in excessive groundwater withdrawal, leading to a decline in water table levels and deterioration of water quality. Surface water scarcity and erratic rainfall in these districts force communities to rely heavily on groundwater, increasing the risk of overuse and contamination. Unregulated pumping, inefficient agricultural water use, and inadequate recharge mechanisms contribute to the depletion of aquifers and the migration from freshwater to brackish and saline conditions. Hydrochemical indicators such as pH, nitrate, fluoride, magnesium, sulphate, and electrical conductivity serve as vital tools for assessing groundwater quality, revealing both natural and anthropogenic influences on water chemistry. Remote sensing and geospatial information systems (GIS) have emerged as indispensable tools for evaluating the spatial and temporal variability of groundwater parameters. These technologies enable comprehensive mapping of quality indicators, vulnerability zones, and land use changes, providing insights for sustainable groundwater management. The combination of field-based hydrochemical analysis and advanced geospatial techniques empowers researchers and policymakers to detect emerging threats, design targeted interventions, and track the success of conservation efforts. Given the increasing pressures on groundwater in Bhiwani and Hisar, a

systematic study of quality trends and spatial patterns is both timely and essential. This research integrates laboratory hydrochemical data with spatial modeling to map the evolution of groundwater quality types from 2019 to 2023, highlighting the pressing need for data-driven policy and resource management in Haryana’s water-stressed districts.

## **2. LITERATURE REVIEW**

Abdekareem et al. (2022) showcased the utility of GIS-based AHP-weighted overlay techniques combined with remote sensing data to enhance groundwater sustainability in arid environments. Their study demonstrated that the fusion of multi-source datasets and analytical hierarchical processes can effectively pinpoint groundwater zones and improve resource planning. Several studies have focused on mapping groundwater potential using geospatial tools. Bera et al. (2020) applied AHP (Analytical Hierarchy Process) and geospatial methods to delineate potential zones in the Karha river basin, Maharashtra, illustrating the effectiveness of multi-criteria decision analysis for regional groundwater exploration. Similarly, Lee et al. (2020) leveraged machine learning techniques with remote sensing and GIS to produce accurate groundwater potential maps, emphasizing the promise of data-driven approaches in resource evaluation. The role of geospatial analysis in flood and hazard management has also been underlined. Chakraborty et al. (2023) employed state-of-the-art geospatial techniques for flood mitigation and policy recommendations, showing how integrated spatial analysis can inform disaster management strategies. Hamid et al. (2020) examined the environmental sensitivity of flash flood hazards using geospatial data, highlighting the interconnectedness of groundwater and surface water phenomena in environmental management. Focusing specifically on groundwater, Pal et al. (2020) assessed groundwater potential in West Bengal using geospatial techniques, while Rehman et al. (2024) mapped groundwater potential zones using integrated remote sensing and GIS-based models, reinforcing the importance of spatial modeling for sustainable resource management. Recent research by Shaikh and Birajdar (2024) reviewed advancements in remote sensing and GIS for groundwater monitoring, discussing current applications, challenges, and future directions for sustainable water management.

## **3. SCOPE OF THE STUDY**

This study focuses on the assessment of key groundwater quality parameters—including nitrate, magnesium, fluoride, sulphate, pH, and electrical conductivity—in Bhiwani and Hisar districts. It aims to identify spatial and temporal changes in groundwater quality and delineate vulnerable zones using advanced geospatial techniques. The research also investigates the relationship between land use changes and groundwater degradation, providing actionable data for sustainable water resource planning and pollution mitigation.

## **4. OBJECTIVE**

- To analyze the spatial distribution and temporal trends of major groundwater quality parameters in Bhiwani and Hisar districts.
- To perform hydrochemical assessments for understanding the status and vulnerability of groundwater.
- To utilize geospatial and statistical techniques for mapping groundwater quality and identifying risk-prone areas.

## 5. RESEARCH METHODOLOGY

The research employs an integrated approach combining field sampling, laboratory hydrochemical analysis, and geospatial modeling. Groundwater samples were collected from representative wells across Bhiwani and Hisar between 2019 and 2023. Key parameters—nitrate, magnesium, fluoride, sulphate, pH, and electrical conductivity—were analyzed following standard protocols. Spatial distribution maps were generated using GIS, applying IDW interpolation and Random Forest classification for vulnerability assessment. Land use and land cover data were incorporated to examine correlations with groundwater quality. The methodological framework ensures robust, data-driven insights for regional groundwater management.

## 6. RESULT AND DISCUSSION

The spatio-temporal analysis of groundwater quality in Bhiwani and Hisar districts revealed substantial changes in the distribution of freshwater, brackish, and saline water zones over the study period (2019–2023). The results indicate a marked decline in the area classified as freshwater, accompanied by a corresponding increase in brackish zones. This trend highlights the ongoing stress on groundwater resources, likely due to anthropogenic activities such as over-pumping, expanded irrigation, and insufficient recharge. The emergence of a small saline water area in 2023, though minimal, is a concerning indicator of advancing water quality deterioration. The decline of freshwater zones and the expansion of brackish water suggest increasing vulnerability of aquifers to both quantity and quality challenges, underscoring the need for immediate attention to groundwater management and policy enforcement.

**Table 1: Details on the area's size (km<sup>2</sup>), pH, and groundwater quality with reference to salinity factors from 2019 to 2023**

Groundwater Quality Type according to pH	Distribution of Area (km <sup>2</sup> ) in Year				
	2019	2020	2021	2022	2023
Fresh Water	110.22	87.05	81.05	75.77	69.40
Brackish Water	29.08	55.05	59.20	70.30	69.90
Saltwater	-	-	-	-	0.01

Table 1 presents the year-wise distribution of groundwater quality types—categorized by pH and salinity—across Bhiwani and Hisar districts from 2019 to 2023. The data reveal a notable contraction in freshwater area, decreasing from 110.22 km<sup>2</sup> in 2019 to 69.40 km<sup>2</sup> by 2023, a reduction of nearly 37%. In contrast, brackish water areas increased from 29.08 km<sup>2</sup> in 2019 to 69.90 km<sup>2</sup> in 2023, overtaking the freshwater zone in both area and trend. Saltwater presence was negligible, appearing only in 2023 at 0.01 km<sup>2</sup>. These figures demonstrate a clear shift from potable to non-potable water categories over the years. The temporal pattern suggests that ongoing overexploitation, land use changes, and possibly pollution are driving the degradation of groundwater quality. The results further indicate that interventions must prioritize both

conservation and remediation, particularly in regions showing rapid transitions toward brackish or saline conditions. Effective policies, artificial recharge, and sustainable withdrawal practices are essential to reverse or halt these negative trends.

## 7. CONCLUSION

This study demonstrates that groundwater quality in Bhiwani and Hisar districts has undergone significant spatial and temporal changes, with a clear trend toward declining freshwater resources and increasing brackish areas. The application of hydrochemical analysis and geospatial mapping has provided valuable insights into the dynamics of groundwater deterioration. Immediate and coordinated interventions, including sustainable management practices, pollution control, and recharge enhancement, are crucial for protecting and restoring groundwater resources in these water-stressed regions of Haryana.

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