

GROUNDWATER QUALITY ASSESSMENT USING REMOTE SENSING AND GIS IN COLLEGE CAMPUS

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Abstract : Groundwater is one of the most important sources of freshwater used for drinking, domestic, and agricultural purposes. However, increasing urbanization, population growth, and human activities have significantly affected groundwater quality. This study focuses on assessing groundwater quality within a college campus using an integrated approach combining field analysis, Remote Sensing, and Geographic Information Systems (GIS). Groundwater samples were collected from multiple locations and analyzed for key physico-chemical parameters such as pH, Total Dissolved Solids (TDS), alkalinity, hardness, and chloride concentration. The obtained results were compared with standard limits prescribed by the Bureau of Indian Standards (BIS) and World Health Organization (WHO). Spatial analysis using GIS techniques was performed to generate thematic maps representing the distribution of water quality parameters. The integration of laboratory data with geospatial tools provides better visualization and understanding of groundwater conditions. The study concludes that groundwater quality within the campus is generally suitable for domestic use, while emphasizing the importance of continuous monitoring and sustainable management practices.

IndexTerms -Groundwater Quality, Remote Sensing, GIS, Water Analysis, Spatial Mapping.

I.INTRODUCTION

Groundwater plays a vital role in meeting the increasing demand for freshwater resources. It is widely used for drinking, irrigation, and domestic purposes. However, due to rapid urbanization and human activities, groundwater quality has been deteriorating in many regions. Traditional methods of groundwater assessment rely mainly on laboratory analysis, which provides accurate results but lacks spatial representation. This creates a gap between data collection and effective decision-making.

To overcome these limitations, this study integrates field-based water quality analysis with modern technologies such as Remote Sensing and GIS. This approach enables better visualization of spatial variations and supports effective groundwater management. The study aims to evaluate groundwater quality across a college campus, identify variations, and provide insights for sustainable utilization of water resources.

II.NEED OF THE STUDY

With the increasing demand for water in institutional campuses, maintaining groundwater quality has become essential. Improper management may lead to contamination, health risks, and environmental issues.

This study is necessary to:

- Identify groundwater quality status across different locations
- Detect spatial variations in water quality
- Ensure suitability for drinking and domestic purposes
- Support sustainable groundwater management

III.RESEARCH WORKS:

Spatial Variability of Groundwater Quality Data The fundamental challenge in groundwater quality assessment arises from the inherent spatial and temporal variability of hydrochemical parameters. Studies in hydrogeology highlight that groundwater quality is influenced by geological formations, soil characteristics, climatic conditions, and anthropogenic activities. Traditional

monitoring methods, based on point sampling, often fail to capture this variability, resulting in fragmented understanding of groundwater systems.

Conventional Physico-Chemical Analysis Approaches Early research focused on laboratory-based analysis of groundwater using parameters such as pH, Total Dissolved Solids (TDS), hardness, alkalinity, and chloride. These values were compared with standards prescribed by organizations like the Bureau of Indian Standards (BIS) and World Health Organization (WHO). While these methods ensured accuracy, they lacked spatial representation, limiting their effectiveness in large-scale environmental assessment.

Emergence of GIS-Based Groundwater Analysis With advancements in geospatial technology, Geographic Information Systems (GIS) became a key tool for groundwater quality assessment. Researchers demonstrated that GIS enables integration of spatial and attribute data, allowing the creation of thematic maps that visually represent groundwater quality distribution. This marked a shift from isolated data analysis to spatial interpretation.

Application of Remote Sensing in Water Resource Studies Remote Sensing technologies introduced the ability to analyze large-scale environmental factors influencing groundwater quality. Satellite imagery has been widely used to study land use and land cover (LULC), vegetation patterns, drainage systems, and recharge zones. These factors play a critical role in determining groundwater contamination and recharge potential.

Development of Spatial Interpolation Techniques To overcome the limitations of discrete sampling, researchers introduced spatial interpolation methods such as Inverse Distance Weighting (IDW) and Kriging. These techniques estimate groundwater quality values at unsampled locations, enabling the generation of continuous surface maps. Studies confirm that interpolation significantly improves the identification of contamination zones and spatial trends.

Integration of GIS with Hydro chemical and Statistical Models Recent studies have combined GIS with statistical techniques such as correlation analysis, principal component analysis (PCA), and Water Quality Index (WQI). These integrated approaches simplify complex datasets and help identify pollution sources, relationships between parameters, and overall water quality status, enhancing decision-making capabilities.

Role of Data-Driven and Intelligent Systems in Environmental Monitoring Modern research is exploring the application of data-driven approaches, including machine learning, for groundwater quality prediction and classification. These models analyze historical data to identify patterns and predict contamination trends. However, similar to other domains, purely data-driven models face challenges in interpretability and reliability for environmental decision-making.

Towards Integrated and Sustainable Groundwater Monitoring Systems Contemporary research emphasizes the need for integrated systems that combine field data, GIS, Remote Sensing, and real-time monitoring. Advanced approaches propose dynamic frameworks where environmental data is continuously updated and analyzed to support sustainable groundwater management. Such systems enable early detection of contamination, improved resource planning, and long-term environmental protection.

IV. PROPOSED APPROACH:

The primary objective of this study is to develop a systematic and integrated approach for assessing groundwater quality within a college campus using a combination of field investigation, laboratory analysis, and geospatial techniques. The proposed approach aims to overcome the limitations of conventional groundwater assessment methods by incorporating Geographic Information Systems (GIS) and Remote Sensing for effective spatial analysis and visualization. Unlike traditional methods that rely only on point-based sampling and laboratory results, this approach emphasizes the integration of hydro chemical data with spatial information to understand the variation of groundwater quality across the study area. This enables better interpretation of groundwater conditions and supports sustainable water resource management.

A. Methodology Framework

➤ The study involves systematic groundwater quality assessment across a college campus using field sampling, laboratory analysis, and GIS tools. Sampling locations are selected based on land use patterns such as academic, residential, and open areas. Groundwater samples are collected using standardized procedures and analyzed for key physico-chemical parameters including pH, TDS, turbidity, hardness, and chloride.

- The collected data is organized in tabular form with unique IDs and geographic coordinates, ensuring accuracy and consistency. Using GIS software like QGIS, sampling points are plotted on a base map prepared from remote sensing data. Laboratory results are linked as attribute data to create a spatial database.
- Spatial interpolation techniques such as IDW are applied to estimate values at unsampled locations, generating thematic maps that show the distribution of groundwater quality parameters. These maps help visualize spatial variations clearly.
- The results are compared with standards set by Bureau of Indian Standards and World Health Organisation to evaluate water suitability for drinking and domestic use. Areas exceeding permissible limits are identified for monitoring.
- Overall, the methodology integrates fieldwork, laboratory analysis, and geospatial techniques in a structured workflow—from sampling to interpretation—ensuring accurate, reliable, and efficient groundwater quality assessment.

B. Functional Significance of the Approach

The proposed approach provides a comprehensive framework for groundwater quality assessment by integrating multiple techniques into a single system.

- Enables visualization of spatial variation in groundwater quality.

V. RESULTS AND DISCUSSION

This section presents a detailed analysis of groundwater quality within the college campus based on laboratory testing and GIS-based spatial mapping. Groundwater samples were collected from multiple locations over a period of four months (December to March) to understand both spatial and temporal variations in water quality. The collected samples were analyzed for key physicochemical parameters such as **pH**, **Total Dissolved Solids (TDS)**, **turbidity**, **total hardness**, and **chloride concentration**. The results were interpreted and visualized using Geographic Information System (GIS) techniques to identify patterns and variations across the study area.

A. pH Analysis

The pH values of groundwater were within acceptable drinking limits and mostly near neutral, indicating stable conditions. Minor seasonal variations occurred, with slight dilution during monsoon and higher values in dry periods. GIS analysis showed uniform pH distribution across the campus, with more stability in vegetated and open areas due to natural filtration.

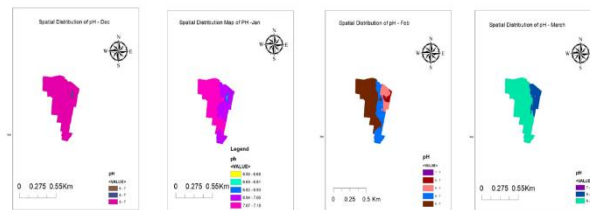


Figure 2: Spatial Distribution Map of pH (Dec - Mar)

B. Total Dissolved Solids (TDS) Analysis

TDS values showed moderate variation, with higher levels in high-activity areas and lower levels in vegetated zones. Seasonal dilution reduced TDS during recharge periods. Overall, values were within permissible limits and suitable for domestic use.

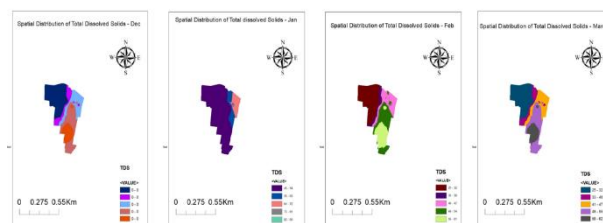


Figure 3: Spatial Distribution Map of TDS (Dec -Mar)

C. Alkalinity Analysis

Alkalinity levels were within acceptable limits, indicating stable groundwater. Minor variations occurred due to soil and geological factors. GIS analysis showed moderate alkalinity across the campus, with better balance in recharge areas, making the water suitable for domestic use.

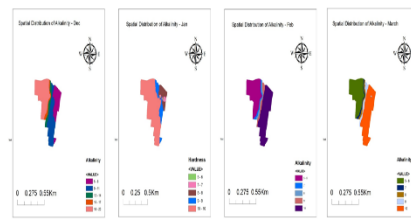


Figure 4: Spatial Distribution Map of Alkalinity (Dec -Mar)

D. Hardness and Chloride Analysis

Total hardness in groundwater, mainly caused by calcium and magnesium ions, was found to be at moderate levels across the study area. Spatial variation was observed due to differences in soil composition and geological formations, with higher values in mineral-rich zones. However, all values remained within permissible limits. Although hardness does not pose serious health risks, it may lead to scaling in pipes and equipment.

Chloride concentration, an important indicator of groundwater contamination, was also within acceptable limits throughout the study area. Minor variations were observed in certain locations due to factors such as soil characteristics, human activities, and groundwater recharge. GIS-based mapping helped identify areas with relatively higher concentrations. Overall, the results indicate no significant contamination from sewage or industrial sources, confirming that the groundwater is suitable for use.

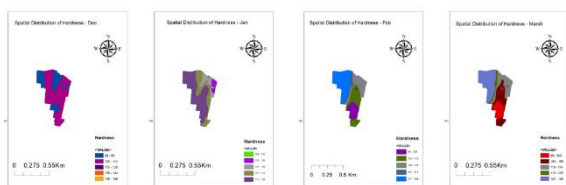


Figure 5: Spatial Distribution Map of Hardness (Dec – Mar)

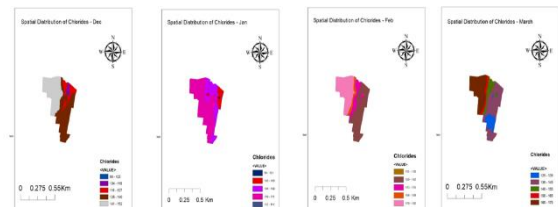


Figure 6: Spatial Distribution Map of Chlorides (Dec -Mar)

GIS-Based Spatial Interpretation

The integration of laboratory results with GIS mapping provides a comprehensive understanding of groundwater quality. Spatial interpolation techniques such as Inverse Distance Weighting (IDW) were used to generate continuous surface maps for each parameter, enabling estimation of values at unsampled locations. The GIS maps clearly demonstrate that groundwater quality varies across different regions of the campus due to natural and anthropogenic factors. Open and vegetated areas generally exhibit better water quality due to enhanced infiltration and recharge, whereas built-up areas show relatively higher concentrations of certain parameters. This spatial visualization helps in identifying potential areas of concern and supports effective decision-making for groundwater management.

In addition, the use of GIS-based spatial analysis enhances the interpretation of complex groundwater data by converting numerical values into visual representations. The generated thematic maps allow easy comparison of different parameters across the study area and help in identifying trends and patterns in water quality variation. This approach improves the efficiency of environmental monitoring and provides a scientific basis for planning, management, and sustainable utilization of groundwater resources.

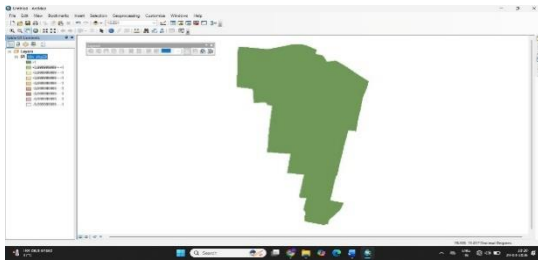


Figure 7: Study Area Map of College Campus

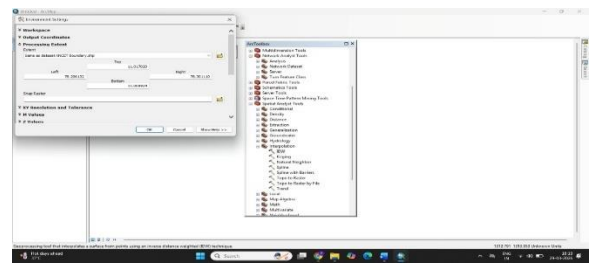


Figure 8: Interpolation Input

Comparative Evaluation with Standards

The analyzed groundwater quality parameters were compared with standard limits prescribed by the **Bureau of Indian Standards (BIS)** and **World Health Organization (WHO)**.

The comparison indicates that:

- pH values are within acceptable limits
- TDS levels are moderate and safe
- Turbidity levels are low
- Hardness is within permissible range
- Chloride concentrations are safe

This confirms that groundwater within the campus is **suitable for drinking and domestic purposes**.

Overall Interpretation

The overall analysis indicates that groundwater quality within the study area is generally good and suitable for use. However, minor spatial variations highlight the influence of land use patterns, geological conditions, and seasonal changes. The use of GIS and Remote Sensing techniques significantly improves the understanding of groundwater quality by providing clear visualization of spatial variations. This integrated approach is highly effective for environmental monitoring and sustainable groundwater management. Continuous monitoring and proper water management practices are recommended to maintain groundwater quality and ensure long-term sustainability.

CONCLUSION AND FUTURE WORK

The study concluded that groundwater quality within the college campus was systematically assessed through field sampling, laboratory analysis, and GIS-based spatial mapping. Groundwater samples were collected from multiple locations across the campus to ensure proper representation of the study area. The collected samples were analyzed in the laboratory for various physicochemical parameters including **pH, Total Dissolved Solids (TDS), hardness, alkalinity, chloride**. The obtained results were compared with the standard limits prescribed by BIS (IS 10500) for drinking water quality. The analysis revealed that most of the parameters were within permissible limits, indicating that the groundwater is generally safe for **drinking and domestic purposes**. However, slight variations in groundwater quality were observed across different months, which may be attributed to seasonal changes, groundwater recharge, and local environmental conditions. **QGIS software** was used for spatial analysis, enabling effective visualization of groundwater quality variations across the study area.

Spatial interpolation using the Inverse Distance Weighting (IDW) method was applied to estimate parameter values at unsampled locations. This technique helped in generating continuous spatial distribution maps and identifying variations in groundwater quality across the campus. The GIS-based maps provided a clear understanding of the spatial distribution and variation of each parameter, highlighting areas with relatively higher or lower concentrations. Overall, the study confirms that groundwater quality within the campus is satisfactory and suitable for use. The integration of laboratory analysis with GIS mapping proved to be an effective approach for groundwater assessment. However, **regular monitoring and proper groundwater management** practices are recommended to maintain water quality and ensure its long-term sustainability.

FUTURE SCOPE

We plan to improve the groundwater quality assessment study in the future to make it more accurate and effective:

- **Increasing Sampling Locations:** In future, more sampling points can be added to improve the accuracy of groundwater quality analysis.
- **Seasonal Monitoring:** Groundwater quality can be monitored throughout the year to study seasonal variations in detail.
- **Advanced GIS Techniques:** Advanced interpolation methods such as Kriging can be used along with IDW for better spatial accuracy.
- **Water Quality Index (WQI):** A WQI model can be developed to represent overall groundwater quality in a single value.
- **Remote Sensing Integration:** Satellite data can be used to analyze land use and land cover changes affecting groundwater quality.
- **Real-Time Monitoring:** Sensors can be installed for continuous monitoring of groundwater parameters.
- **Prediction Models:** Machine learning techniques can be applied to predict future groundwater quality trends.
- **Groundwater Management:** Implementation of rainwater harvesting and recharge techniques can improve groundwater sustainability.
- **Mobile GIS Applications:** Mobile-based GIS tools can be developed for easy data collection and monitoring in the field.

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