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Assessment of Groundwater Quality Using Geospatial and Modelling Tools

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Abstract
Groundwater originates from porous layer. Groundwater resources are one of the most important sources of water for domestic, agriculture and Industrial use in areas with limited surface water resources. The quality of groundwater now faces deterioration as a result of human and natural activities. Assessing groundwater quality is essential to ensure it is safe and sustainable practices. The development of human beings and natural process has led to a significant declination of water quality. Geospatial technology plays a key role in checking and managing groundwater quality. This study presents an integrated approach to assess groundwater quality missing geospatial and modelling tools, aims to identify spatial distribution and potential contamination zone. Geographic Information System (GIS) is used to read map and analyses water quality parameters such as pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), nitrate, chloride and heavy metal. Inverse Distance Weighting (IDW) is used to visualize the variables of spatial of groundwater quality. The combination of Geographic Information System (GIS) with quantitative statistical and modelling tools enabled at a very high resolution in an efficient grounded methodology. This approach proves to be sustainable groundwater management, groundwater management, environmental protection and public health safety. Overall this study highlights the importance of continuous monitoring and the application of advanced tool to safeguard vital groundwater resources.

Keywords: *Groundwater management, Geographic Information System, Sustainability, Environmental protection, Advanced technology.*

1. Introduction
Groundwater is central to supporting life, especially in those areas where surface water resources are limited. Groundwater is a primary source of water for domestic use, agriculture, and industry. But with the rising rate of urbanization, population growth, and extensive land utilization, groundwater quality is also facing growing vulnerability. Both human activities like excessive usage of fertilizers, uncontrolled dumping of waste, and industrial effluents and natural processes contribute to groundwater quality degradation. Over the last few years, the use of geospatial technologies in hydrogeological research has picked up considerable pace. These technologies not only make spatial patterns easier to visualize but also improve the interpretation of intricate environmental information. Satellite imagery, GIS-based mapping, and field observations combined provide scientists and policymakers with the ability to monitor trends, compare seasonal trends, and analyze groundwater vulnerability more accurately. Especially in developing countries such as regions of India, where resource limitations and data deficiencies are issues, geospatial technology provides a cost-effective, effective means of understanding groundwater systems. In addition, groundwater quality evaluation is not only a technical requirement but also a critical component in solving larger environmental and societal problems. Deterioration of the quality of groundwater can have extremely adverse health implications, ranging from

waterborne ailments to prolonged exposures to toxic trace elements such as nitrates and heavy metals. Using powerful tools and simulation techniques, the research will contribute to closing science-policy gaps while providing knowledge able to guide approaches to groundwater conservation, inform water protection policy, and shape the regulatory agenda that can serve generations to come. With increasing water quality and sustainability concerns, there is a need for efficient and accurate means of evaluating groundwater conditions. Conventional methods, though valuable, tend not to possess the spatial and temporal resolution needed for effective management. Here, geospatial techniques like Geographic Information Systems (GIS) and Remote Sensing (RS) provide the means for mapping, analyzing, and monitoring groundwater quality at large scales. Additionally, when geospatial analysis is used in conjunction with modeling methods, including Inverse Distance Weighting (IDW) and statistical packages, it makes possible a more accurate and integrated description of groundwater processes. These combined techniques have the capability to detect space patterns, map areas of contamination, and assist in data-based decision-making for the management of groundwater sustainably. This research is directed towards utilizing geospatial technology and modeling methods to evaluate the quality of groundwater through the evaluation of important parameters like pH, total dissolved solids (TDS), electrical conductivity (EC), nitrates, chlorides, and heavy metals. It aims to delineate spatial variation, identify zones of possible contamination, and thereby support sustainable public health and environmental protection.

2. Methodology

The current research on groundwater quality evaluation was carried out on the basis of secondary data sources, thus avoiding primary data collection and field observations. The area of study was chosen on the basis of its high reliance on groundwater for drinking, agriculture, and industry. The hydrogeological nature, land use pattern, and population profile of the area were initially comprehended by satellite imagery and government-brought-out data. The data on groundwater quality was obtained from authentic secondary websites such as the Central Ground Water Board (CGWB), India-WRIS portal, Bhuvan (ISRO), and state-level groundwater departments. Data and reports present on such sites furnished details of important water quality parameters like pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Nitrate, Chloride, and heavy metals such as Iron and Arsenic. These parameters were selected because they are pertinent to public health and also common in groundwater research. Geographic Information System (GIS) software, namely QGIS and ArcGIS, were employed to manage and process the spatial data. The georeferencing of the sampling points from secondary datasets was performed using the latitude and longitude values included in the reports. A spatial database was developed by merging this point data with related water quality attributes. The geographical variability of all parameters was subsequently displayed using Inverse Distance Weighting (IDW) interpolation. This procedure permitted the production of continuous surface maps, aiding the detection of hotspots of pollution and zones of safety. In order to simplify interpretation and supply a general water quality assessment, the Water Quality Index (WQI) was determined. The WQI calculation was done using the weighted arithmetic index approach, where every parameter was given a weight based on its contribution to water quality. The index facilitated the classification of groundwater quality into excellent, good, moderate, poor, and very poor categories. The calculated WQI values were further utilized to create groundwater quality zoning maps in the GIS platform. The results derived from the interpolation and WQI analysis were also verified by cross-checking the same with previous research study findings as well as government reports. As ground-truthing was not feasible since no fieldwork was conducted, cross-verification of various sources of information and prior consideration of the latest and official data sets was ensured. In general, the use of geospatial technology combined with statistical software and secondary data offered a low-cost and effective method of interpreting and mapping groundwater quality within the study area. Figure 1

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shows Methodology Flowchart.

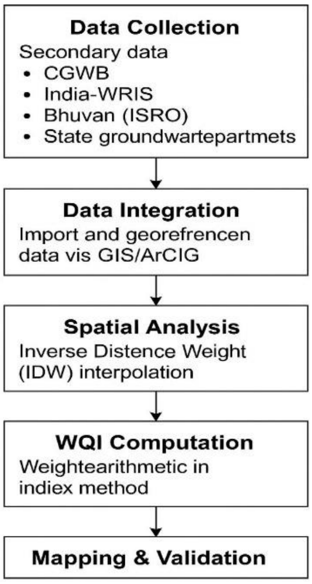

Figure 1 **Methodology Flowchart**

Table 1 **Comparison Table of Groundwater Quality**

City	pH	TDS (mg/L) Total Dissolved Solid	EC (µS/cm) Electrical Conductivity	Nitrate (mg/L)	Chloride (mg/L)
Chennai	7.1	520	850	18	80
Coimbatore	7.4	430	790	10	60
Salem	7.0	580	910	25	95
Trichy	7.3	470	780	12	55
Madurai	6.9	600	950	22	90
Thoothukudi	7.2	640	980	28	105

The pH of the groundwater should ideally be between 6.5 and 8.5 so that the water is neither too acidic nor too alkaline. Water outside these limits could lead to corrosion, scaling, or health problems. Total Dissolved Solids (TDS) are the concentration of dissolved matter and must be less than 500 mg/L for good quality drinking water, although up to 2000 mg/L is acceptable if alternatives are not available. High TDS impacts taste, palatability, and scaling in pipes. Directly proportional to TDS is Electrical Conductivity (EC), which measures the amount of minerals present; below 1500 µS/cm is acceptable. Nitrate is another important parameter, and the maximum permissible limit is 45 mg/L. High nitrate concentrations are dangerous, particularly to infants, as they lead to diseases such as methemoglobinemia or "blue baby syndrome." Chloride levels should be less than 250 mg/L, with a permissible limit of 1000 mg/L; high chloride content makes water taste salty and can lead to hypertension and corrosion. Iron must not exceed 0.3 mg/L since it can stain clothes and utensils and affect taste of the water. These parameters are crucial for ensuring the safety of ground water. The groundwater quality information of six key cities of Tamil Nadu Chennai, Coimbatore, Salem, Trichy, Madurai, and Thoothukudi was evaluated on the basis of major water quality parameters such as pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Nitrate, and Chloride. The values of pH in all the cities were found to vary from 6.9 to 7.4, which shows that the water is mostly neutral to slightly alkaline, which is in acceptable limits for consumption. TDS concentrations ranged from 430 mg/L in Coimbatore to 640 mg/L in Thoothukudi, and the values increased with the amount of dissolved content, having a potential influence on taste and health. Electrical Conductivity, which is a measure of the mineral content, was maximum in Thoothukudi (980 µS/cm) and minimum in Trichy (780 µS/cm). Nitrate content was found to be highest in Thoothukudi (28 mg/L) and Salem (25 mg/L), possibly due to runoff from agriculture or sewage contamination. Concentrations of chloride were also the highest in Thoothukudi (105 mg/L), indicating probable salinity intrusion or industrial pollution. On a whole, Thoothukudi reveals relatively higher values in the majority of the parameters, indicating a requirement for regular monitoring, while other cities like Coimbatore and Trichy reflect relatively better groundwater quality.

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Table 1 shows Comparison Table of Groundwater Quality.

3. Results

Groundwater quality evaluation of six chosen cities of Tamil Nadu exhibits a large variability in water parameters affected by urbanization, industrialization, and local hydrogeology. Every pH value obtained in all locations of Chennai, Coimbatore, Salem, Trichy, Madurai, and Thoothukudi is between the standard limit of 6.5 and 8.5, signifying no instantaneous acidity or alkalinity problems. Total Dissolved Solids (TDS) were lowest at Coimbatore (430 mg/L), reflecting comparatively fresh water, and Thoothukudi (640 mg/L) and Madurai (600 mg/L) recorded higher levels, reflecting higher dissolved mineral content potentially influencing taste and palatability. The trend was the same in Electrical Conductivity (EC), with 980 µS/cm being the highest reading from Thoothukudi, indicating high ionic concentration and potential salinity problem. Nitrate concentrations, a very important parameter for health, were very high in Salem (25 mg/L) and Thoothukudi (28 mg/L), though still within safe limits (45 mg/L), suggesting possible anthropogenic contamination from sewage or fertilizers. Chloride concentrations showed a similar trend with the highest value at Thoothukudi (105 mg/L), possibly suggesting saline intrusion or outfall from coastal or industrial operations nearby. Urban areas such as Coimbatore and Trichy presented comparatively lower values in most of the parameters, indicating improved groundwater quality and lesser risks from sources of contamination. According to the Water Quality Index (WQI) determined based on weighted scores for all parameters, Coimbatore and Trichy belong to the "Good" category, meaning that their groundwater is safe for drinking with little treatment. Chennai and Salem are classified as "Moderate" for which water is suitable but needs basic treatment. Madurai and Thoothukudi are in the "Poor" category, indicating a requirement for more frequent monitoring and potential remediation to prevent health concerns. These findings stress the need for local management of water resources, particularly in urban and coastal areas where point sources of pollution are denser.

4. Discussion

The approach employed in this study illustrates the applicability of the utilization of secondary data in combination with geospatial tools in determining groundwater quality effectively. By employing authentic sources of data such as CGWB, India-WRIS, Bhuvan (ISRO), and state groundwater boards, the study bypasses the logistic and financial drawbacks of primary data collection without losing scientific authenticity. The incorporation of Geographic Information System (GIS) software, such as QGIS and ArcGIS, enabled the spatial analysis of water quality parameters in several urban areas. Georeferenced sampling points and interpolation methods such as Inverse Distance Weighting (IDW) were found useful in the visualization of spatial trends, contamination hotspots, and safe zones. In addition, the Water Quality Index calculation employing a weighted arithmetic approach offered an uncomplicated and standardized method of evaluating overall water quality to facilitate better comparison among regions. This approach is particularly suitable for large-scale or exploratory groundwater investigations where obtaining field data is time-, cost-, or access-limited. Though the use of secondary data had some restrictions, for instance, a lack of real-time values and potential inconsistencies in data collection methods, the cross-verification across several sources made sure that the data was reliable. From a general perspective, the methodology adopted in this research offers a cost-efficient and scalable solution, as well as an indication of how sophisticated geospatial and statistical approaches can be utilized in the provision of support for sustainable groundwater resource management and policy planning.

Conclusion

The current study successfully illustrates the integration of secondary data and geospatial techniques to evaluate groundwater quality in a cost-effective and scientifically rigorous way. By leveraging data from trusted government agencies and using GIS-based spatial analysis, the research was able to map and interpret critical water quality parameters in various urban areas. The application of Inverse Distance Weighting (IDW) interpolation and the Water Quality Index (WQI) gave explicit information on the spatial distribution and general status of groundwater in the research areas. The method was useful not only in the determination of pollution hotspots but also in assisting decision-makers with actionable information for water Resource management.

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