J. Ind. Geophys. Union, 29(5) (2025), 321-338
https://doi.org/10.71122/JIGU.29(5)2025.0031

Geospatial assessment of groundwater quality and its suitability for drinking and irrigation in semi-arid regions of Andhra Pradesh (India) using water quality index approach

Ravi Kumar Pappaka[1], Srinivasa Gowd Somagouni[1*] Krupavathi Chinthala[1], and Pradeep Kumar Badapalli [2]
[1]Dept of Geology, Yogi Vemana University, YSR Kadapa- 516005, Andhra Pradesh (India)
[2]CSIR-National Geophysical Research Institute, Hyderabad-500007, Telangana (India)
*Corresponding author: ssgowd@gmail.com

ABSTRACT

Groundwater, a vital resource for drinking and irrigation in the semi-arid regions of Andhra Pradesh, is increasingly threatened by rapid depletion and quality deterioration due to growing demands from intensive agriculture and population expansion. In this study, a total of 92 groundwater samples were collected from boreholes during the pre-monsoon (PRM) and post-monsoon (POM) seasons, and their physicochemical properties were systematically analyzed. The major ion sequence in the groundwater was found to be $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ for cations, and $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^- > F^-$ for anions. During the PRM season, only 19% of the samples met drinking water standards, with Water Quality Index (WQI) values ranging from 59.18 to 172.21. In the POM season, 22% of the samples were deemed safe for drinking, with WQI values ranging from 70.07 to 229.46. The majority of the samples were unsafe due to contamination from human activities, including improper sewage disposal and agricultural runoff. To assess the suitability of groundwater for agricultural and domestic use, Gibbs, USSL, and Wilcox diagrams were utilized. The Gibbs plot indicated that rock dominance governs the groundwater chemistry in the region. Most samples were highly suitable for irrigation, as evidenced by favorable Sodium Adsorption Ratio (SAR), %Na, Soluble Sodium Percentage (SSP), Kelly's Ratio (KR), Residual Sodium Carbonate (RSC), and Permeability Index (PI) values. The Piper diagram revealed a prevalence of Ca^{2+}-HCO_3^- and Ca^{2+}-Mg^{2+}-Cl^- water types. Using Geographic Information System (GIS) techniques, the spatial distribution of groundwater quality was mapped, showing that the majority of samples failed to meet drinking water quality standards, thus necessitating treatment before consumption. Groundwater with elevated concentrations of fluoride and nitrate is unsuitable for drinking purposes and should be avoided. The findings underscore the urgent need for sustainable aquifer management strategies to ensure the continued availability of safe groundwater for both domestic and agricultural use.

Keywords: Hydrogeochemistry, Water Quality Index (WQI), Drinking water and irrigation, Remote sensing and GIS, Spatial distribution maps, Semi-arid region, Pandameru River Basin

INTRODUCTION

Water is an essential resource that sustains life across ecosystems, supporting both plant and animal life. However, the quality of groundwater, an important source for drinking and irrigation, is deteriorating due to a combination of natural processes and anthropogenic activities. Factors such as rising temperatures, industrial discharge, and intensified agricultural practices are exacerbating water quality degradation, posing significant health risks to both aquatic and terrestrial ecosystems (Badapalli et al., 2024). These concerns highlight the need for comprehensive groundwater quality monitoring to protect ecological integrity and anticipate future environmental changes (Khatri et al., 2020; Parveen et al., 2025).

The purity of groundwater is influenced by both geogenic and anthropogenic factors. With increasing industrialization and the expansion of modern agricultural practices, untreated waste and surface runoff often enter the groundwater system, disrupting ecological balance (Gugulothu et al., 2022; Molagamudi et al., 2023). Groundwater quality is governed by multiple factors, including the chemical composition of surrounding rocks and soils, seasonal rainfall patterns, aquifer dynamics, and human activities such as the improper disposal of waste into poorly constructed wells. As groundwater percolates through weathered rock layers, its chemistry is altered by regional geology, flow patterns, and mineral interactions, all of which collectively shape its quality.

Understanding hydrogeochemical processes is essential for identifying and managing contamination sources in groundwater. Small amounts of metal ions are essential for health, yet excess exposure can be toxic or even carcinogenic. The rise of newly developed chemicals further threatens water resources, underscoring the urgent need to mitigate these contaminants (Asadi et al., 2019; Anusha et al., 2022). Innovative solutions, such as the use of nano-adsorbents, are under investigation to remove pollutants; however, local geochemical processes play a substantial role in defining groundwater chemistry and require careful analysis.

In India, the quality of groundwater, especially in hard rock terrains like Anantapur, Andhra Pradesh, is declining due to population growth, intensive groundwater extraction, and excessive fertilizer use. Numerous studies have analyzed the impact of human activities such as wastewater discharge, agricultural chemicals, and water-rock interactions on groundwater, highlighting the need for strategies to improve groundwater suitability for drinking, agricultural, and industrial use (Subba Rao et al., 2019; Nayak et al., 2023). In the semi-arid Pandameru River basin, Andhra Pradesh, groundwater accounts for 80-90% of water needs, necessitating immediate action to safeguard this essential resource (Pappaka et al., 2024).

Water Quality Index (WQI) is a widely recognized tool for assessing groundwater suitability. Unlike traditional evaluation