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Magnetic investigation of structural controls on groundwater contamination and flow pathways along the Musi River, Ranga Reddy and Nalgonda districts, Telangana (India)

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ABSTRACT

Magnetic investigations were conducted along the Musi River corridor between Peerzadhiguda and Valigonda areas, encompassing portion of the Ranga Reddy and Nalgonda districts in the state of Telangana, India, to delineate subsurface structural controls governing groundwater flow and contaminant migration. A total of 1,260 magnetic measurements were acquired along twelve traverses at 100 m station intervals and processed using magnetic anomaly mapping, Reduction to the Pole (RTP), and Analytical Signal (AS) techniques. The magnetic anomaly analysis identified seven prominent magnetic highs and four magnetic lows, indicating structurally controlled subsurface heterogeneity. Radial Average Power Spectrum (RAPS) analysis revealed three characteristic depth interfaces at approximately ~0.1 km, ~0.5 km, and ~1.6 km corresponding to weathered, semi-weathered and fractured granitic-gneissic basement. Two-dimensional magnetic modelling further constrained shallow structural bodies with depths ranging from ~0.12 – 0.22 km and lateral extents up to ~2 km, indicating broader and more complex fractured zones in the downstream sector. An integrated structural map revealed dominant NE–SW, NW–SE, and N–S lineament trends, with comparatively greater structural complexity in the downstream sector. The spatial correspondence between magnetic gradients, mapped geological structures, and modelled bodies indicates that faults, dykes, and fracture networks, act as preferential pathways of controlling groundwater flow and facilitating contaminant migration along the Musi River corridor.

Keywords: Magnetic anomaly; Reduction to the Pole; Radial Average Power Spectrum (RAPS); Analytical signal; Structural lineaments; Groundwater contamination; Musi River Basin (Telangana).

INTRODUCTION

The Musi River, flowing through the heart of the Hyderabad city in Telangana state, India, plays a critical role in sustaining urban and peri-urban communities. However, rapid urbanization, industrialization, and unregulated waste disposal have severely affected the river's hydrological and geochemical integrity (Phani and Rajendra Prasad, 2024). Numerous environmentalists, hydrologists, and geoscientists have investigated groundwater quality and pollution patterns within the Musi River basin, highlighting the urgent need for structural and geophysical investigations to understand subsurface contamination mechanisms. Early studies by Barker (1981) provided foundational insights into groundwater potential and resistivity characteristics in the Musi ayacut region. Subsequent investigations by the Andhra Pradesh State Ground Water Department (2002), enhanced our understanding of aquifer dynamics, recharge processes, and hydrogeological behavior. Later, Sekhar et al. (2005) documented the relationship between industrial activity and heavy metal contamination in the Musi River and adjoining aquifers.

In recent years, environmental geophysics has emerged as a vital interdisciplinary approach for delineating pollution pathways, mapping lithological variations, and characterizing structural controls influencing groundwater contamination (Akpa et al., 2023). Geophysical techniques such as magnetic, electrical resistivity, and electromagnetic methods, provide non-invasive means to detect subsurface anomalies associated with fractures, faults, shear zones, and intrusive dykes, which often govern groundwater flow and contaminant migration (Sharp, 2014; Jogu and Gardas, 2025). Magnetic investigations, in particular, offer a high-resolution tool for mapping near-surface structural heterogeneities, enabling correlation between magnetic anomalies and geological features within the hard rock terrains (Pazzi et al., 2016).

The present study undertakes an integrated qualitative and quantitative magnetic investigation of the Musi River segment between Peerzadhiguda and Valigonda areas, encompassing portion of the Ranga Reddy and Nalgonda districts in the state of Telangana, India. By combining magnetic anomaly, reduction to the pole (RTP), analytical signal (AS), radial average power spectrum (RAPS) analysis, and two-dimensional forward modelling, the study aims to delineate subsurface lineaments, fault zones, and depth interfaces that potentially facilitate pollutant transport.

LOCATION OF STUDY AREA

The study area extends between 17°20′ to 17°25′ N and 78°36′ to 79°02′ E, encompassing portions of the Ranga Reddy and Nalgonda districts in the state of Telangana, India. It is located approximately 20 km east of Hyderabad City in an approximate area of about 417 km² (Figure 1).