Seasonal hydrogeochemical dynamics and leachate influence on peri-urban groundwater

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The present study presents results on temporal hydrochemical facies shifts in groundwater around a municipal solid waste processing plant with a dumpsite in Doddabidarakallu, Bengaluru, India. Over two hydrological cycles (2022–2024), 120 groundwater samples were collected seasonally and analysed for physicochemical parameters, major ions, and heavy metals to assess contamination patterns. Ca–Mg–Cl–SO_4 facies dominated during post-monsoon periods (61.3% in 2022 and 75% in 2023), while Ca–Mg–HCO_3 facies was prominent in the pre-monsoon period of 2023 (45.7%). In pre-monsoon 2024, Ca–Mg–Cl–SO_4 remained dominant (71.4%), indicating contamination pathways influenced by leachate migration and anthropogenic activities. Water quality index classification showed seasonal deterioration, particularly during pre-monsoon periods. Irrigation suitability, assessed via sodium absorption ratio and United States Salinity Laboratory diagrams, indicated high salinity but low sodium hazard. Groundwater composition near the Doddabidarakallu landfill contains many constituents that exceed the World Health Organisation/Bureau of Indian Standards drinking water standards, confirming persistent contamination from legacy waste. Implementing on-site processing at dumping sites can demonstrably prevent, to a significant extent, future contamination by removing and stabilising hazardous materials. Concurrently, continuous groundwater monitoring and adaptive, localised remediation strategies are indispensable for managing the pre-existing contaminant plume and achieving complete environmental restoration.

Keywords: Groundwater contamination, hydrochemical facies, leachate migration, SAR, urban landfill, water quality index.

salinity indices, and introduce toxic contaminants into drinking water sources[1,2]. Despite regulatory mandates under the Solid Waste Management Rules and Central Pollution Control Board (CPCB) guidelines, enforcement remains inconsistent. Comprehensive hydro-geochemical assessments are also scarce[3,4].

India's urban solid waste management has undergone significant reforms in recent years; yet, the challenge of legacy waste—accumulated municipal solid waste (MSW) in open dumpsites—remains a persistent environmental and public health concern[5]. With daily MSW generation exceeding 1.6 lakh tonnes, only half of the quantity gets scientifically treated. The Swachh Bharat Mission 2.0 prioritised the remediation of legacy waste, mandating complete dumpsite clearance by March 2024 for major cities and promoting the transformation of waste zones into green spaces[6]. However, implementation remains uneven across states. In Karnataka, legacy waste occupies over 2,000 acres, with 1.07 crore tonnes concentrated in Bengaluru's dumpsites, including the one at Doddabidarakallu. A statewide assessment of 20 dumpsites revealed that bio-soil—the dominant fraction recovered during remediation—fails to meet Fertiliser (Control) Order (FCO) standards for compost and contains elevated levels of heavy metals, raising concerns about its use in land reclamation and its potential to contaminate groundwater[7].

Recent spatial vulnerability assessments in Bengaluru using the DRASTIC method and the Analytical Hierarchy Process (AHP), integrated with a geographical information system, revealed that over 32% of the city's area falls within a moderate-to-high groundwater vulnerability zone, and none of the existing landfill sites are located in safe zones. This underscores the urgent need for scientifically informed landfill siting and aquifer-protection strategies. Further, only 0.08% of Bengaluru's total area is highly suitable for land filling, highlighting severe land constraints and the importance of reliability-based site selection[8].

The present study examines the groundwater quality