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Seasonal Salinity Dynamics in Coastal Phreatic Aquifers of Kollam District, Kerala, India

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Abstract

This study evaluates the spatial and seasonal dynamics of seawater ingress in the coastal phreatic aquifer systems of Kollam District, Kerala, using an integrated hydrochemical and index-based approach. A total of 21 groundwater samples were collected during the pre- and post-monsoon seasons of 2022 and analysed for major ions and physicochemical parameters. The Groundwater Quality Index for Seawater Mixing (GQI_{SWI}) was employed to identify salinization levels by integrating hydrochemical facies and chloride-derived mixing ratios. The Hill–Piper diagrams of the analysed water samples from the study area showed a shift, with samples transitioning from Na-Cl dominated facies during the pre-monsoon to $Ca–HCO_3$ type in the post-monsoon, indicating freshening of groundwater due to monsoon recharge. Similarly, the USSL diagram displayed a shift in several post-monsoon samples toward lower salinity zones, reflecting the dilution effect of rainfall. An inverse relation between depth to the water table and electrical conductivity was observed across coastal transects, with higher electrical conductivity observed in the shallow coastal zones and a decrease in conductivity with increasing depth towards the east. Despite the overall improvement in water quality during the post-monsoon season, a few localized zones continued to exhibit elevated salinity levels—likely attributable to limited aquifer thickness, proximity to the coastline/saline water bodies. The study demonstrates that monsoonal recharge plays a vital role in reversing salinity levels and provides a replicable framework for seawater ingress assessment and aquifer vulnerability mapping in coastal regions.

Keywords: Kollam District, Seawater Ingress, Seasonal Salinity Dynamics, Coastal Phreatic Aquifer System, Hydrochemical Facies, Ground Water Quality Index

Introduction

Coastal aquifers around the world are increasingly under threat from seawater intrusion, a process driven by a combination of anthropogenic and natural factors. Excessive groundwater abstraction, unregulated urbanization, and climate change-induced sea-level rise are among the most prominent drivers (Bear *et al*., 1999; Werner *et al*., 2013; Singh *et al*., 2021; Abd-Elaty *et al*., 2021; Aju *et al*., 2024; Anisha *et al*., 2025.). The mixing of saline water into freshwater aquifers compromises groundwater quality, reducing its suitability for drinking, agriculture, and industrial uses. This not only endangers human health but also disrupts agricultural productivity and the functioning of coastal ecosystems (Barlow and Reichard, 2010; Ferguson and Gleeson, 2012). In India, coastal aquifers are particularly vulnerable due to their high dependence on groundwater for domestic and agricultural requirements (Bhattacharya, 2020). This is particularly relevant in the coastal stretches of Kerala, where population density is high and surface water availability is seasonally variable; however, the region's high rainfall recharge acts as a natural safeguard against large-scale seawater ingress. The State's lateritic and alluvial aquifer systems are shallow and discontinuous in nature, making them more susceptible to salinization through seawater ingress in response to pumping stress (CGWB, 2023a; Saleena *et al*., 2025). Studies have reported elevated chloride concentrations and electrical conductivity values in observation wells along parts of Kerala's coast, including regions such as Kollam, Alappuzha, Ernakulam, and Kozhikode, which are indicative of localized or seasonal seawater ingress (Nagarajan *et al*., 2018; Suraj *et al*., 2019; Renu *et al*., 2024; Anisha *et al*., 2025). However, it is pertinent to note that localized increase in salinity observed during the pre-monsoon season tends to reverse during the monsoon, primarily due to substantial rainfall recharge. The high volume of precipitation during monsoon period enhances groundwater replenishment and dilution, mitigating salinity buildup in coastal aquifers. In addition to hydrogeological factors, land use changes, including sand

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