KN04 KEYNOTE ADDRESS · WATER SECTOR

Integrated Multi-Proxy Techniques for Assessing Submarine Groundwater Discharge and Saline Intrusion along the Coastal Tracts of South-Eastern India: Implications for Sustainable Water Resources

K. Srinivasamoorthy[1*], G. Ponnumani[1], A. R. Khanna[1], K. Ramesh[1], V. Gopalakrishnan[1] and D. S. Varshini[1]

[1]*Department of Earth Sciences, School of Physical, Chemical, and Applied Sciences, Pondicherry University, Puducherry, India*

**Corresponding author: moorthy.esc@pondiuni.ac.in*

DOI: https://doi.org/10.31705/ICEWSE.2026.4

Abstract

Coastal aquifers are the most vulnerable freshwater resources, threatened by seawater intrusion (SWI), excessive groundwater withdrawal, anthropogenic, and climate-related influences. Further, submarine groundwater discharge (SGD) is groundwater flow from the land to the sea that has emerged as a significant pathway that links groundwater flow from the land to the sea that transports freshwater, dissolved salts, nutrients, trace elements, and Rare Earth Elements (REEs) and other geochemical constituents to the coastal ocean. Recent investigations in the coastal aquifers of southeast India (Tamil Nadu and Puducherry) have identified seawater intrusion affecting 20 to 40% of groundwater resources, and SGD rates of about 0.01 to 0.98 $m^3\ m^{-2}\ d^{-1}$, which transport chemical constituents to the coastal oceans. Hence, it is imperative to understand the dynamics of SWI and SGD for sustainable water resource management. The present study uses multi-proxies that combine direct and field-based measurements, groundwater flow and transport modeling, resistivity investigations (ERT), hydrochemical indicators, radon, nutrients, trace elements, and REEs to identify groundwater dynamics. Darcy law, water budget, and seepage studies provided direct measurements of groundwater flux, while electrical resistivity imaging techniques delineated freshwater, saline water, and subsurface zones and pathways. Groundwater flow modeling was used to isolate the mechanisms and spatial variations of SWI and SGD under diverse geohydrological scenarios. Ionic ratios were used to isolate fresh, saline and mixed groundwater flows. Hydrochemical and geochemical tracers indicate that SGD acts as both source and sink for dissolved constituents through biogeochemical transformations. Radon-derived SGD estimates indicate substantial groundwater contributions to the coastal zone, while ERT confirms the existence of complex freshwater-saltwater transition zones and recirculated seawater pathways. Nutrients predicted SGD fluxes and were found to be influenced by coastal eutrophication, productivity and biogeochemical cycling. Trace elements and REEs identified processes like water-rock interaction, mixing, and geochemical evolution, thereby altering the chemical composition of coastal groundwater. The integrated approach suggested a strong impact of the spatial and temporal variability of SWI and SGD, which is controlled by factors like hydraulic gradients, recharge, and aquifer heterogeneity. Multi-proxy datasets were compared with global studies and found to be comparable with several tropical and subtropical coastal aquifers. The study also highlights the need to integrate multiple techniques for more accurate and reliable assessment of SWI and SGD. The findings provide critical insights for sustainable coastal aquifer management, climate resilience planning, groundwater protection, and the preservation of sensitive coastal ecosystems under increasing environmental stress.

Keywords: *coastal groundwater; nutrients; radon; rare earth elements; resistivity imaging; saline water intrusion; seepage meters; submarine groundwater discharge; sustainable management; trace elements*