

{rokbox title=|a) Sampling locations, well networks, and aquifers in southern and eastern Mallorca; b) Piper diagram for groundwater samples (2023–2024); c) Hydrochemical Facies Evolution Diagram (HFEsingle bondD) illustrating dominant cation–anion facies and salinization/freshening trends (red and blue arrows, respectively) :: Image: Authors| thumb=|images/stories/ieo/imagenespublicaciones/centro-oceanografico-baleares-ieo-csic-multi variate-assessment-groundwater-deudero-2026-thumb-et-al.jpg|}images/stories/ieo/imagenespublicaciones/centro-oceanografico-baleares-ieo-csic-multivariate-assessment-groundwater-deudero-2026-et-al.jpg{/rokbox}

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Multivariate assessment of groundwater contamination levels associated with saline intrusion processes in Mediterranean coastal aquifers

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Abstract: Groundwater in Mediterranean coastal aquifers supplies a large part of the demand for freshwater but is increasingly threatened by seawater intrusion and anthropogenic pollution. During the springs of 2023 and 2024, six coastal carbonate aquifers in Mallorca were sampled to assess the present-day spatial and vertical variability of salinization and pollution. Hydrochemistry showed elevated Cl^- (2140–18,800 mg/L), Na^+ (1317–10,983 mg/L) and SO_4^{2-} (440–2890 mg/L), with high electrical conductivity (7480–53,850 $\mu\text{S}/\text{cm}$ in 2023 and 16,200–42,000 $\mu\text{S}/\text{cm}$ in 2024). Nutrients (NO_3^- , NH_4^+ , PO_4^{3-} , NO_2^-) and fecal indicators (*Escherichia coli*, *Enterococci*) were detected. Vertical profiles showed salinity increases with depth (except at Drac de Santanyí). The f_{sea} index indicated marine intrusion in >96% of samples. Modified Piper indices (GQIPiper(mix), GQIPiper(dom)) and GQISWI values (28–56 in 2023; 32–51 in 2024) pointed to dominant to mixed Nasingle bondCl facies. PCA and hierarchical clustering revealed marked hydrochemical heterogeneity among sites, with differences between 2023 and 2024 and site-specific anomalies associated with freshwater inputs and anthropogenic pressure. Overall, the results document widespread brackish to saline groundwater conditions and the co-occurrence of microbiological contamination in Mallorca's coastal aquifers, highlighting their high vulnerability to salinization and water-quality degradation. This work presents a data-driven, site-specific conceptual model of the marine intrusion system in Mediterranean coastal aquifers, characterized by a laterally extensive brackish zone overlying saline groundwater and a limited or locally absent freshwater lens near the coast. These findings underscore the need for integrated groundwater management, including salinity monitoring, regulation of abstraction, and improved wastewater treatment, to mitigate ecological and public-health risks in Mediterranean coastal aquifer systems.

Keywords: Coastal aquifers, Contamination, Hydrochemistry, Microbiological groundwater indicators, Sustainability management, Seawater intrusion