

Spatial and Temporal Dynamics of a Subterranean Estuary in a High Submarine Groundwater Discharge Zone: Insights from Southwest India

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Subterranean estuaries (STEs) represent crucial ecological interfaces where terrestrial and marine environments converge, yet their dynamics remain incompletely understood due to the intricate interplay of terrestrial and marine influences. This study presents a comprehensive two-year investigation of an STE situated in a high submarine groundwater discharge (SGD) zone in southwestern India. Through high-resolution spatial and temporal monitoring spanning six seasons, we explain the full tidal influence on the STE. Our findings reveal the complex temporal dynamics of seawater recirculation within the STE, highlighting significant seasonal shifts. During the wet season, the proximity of the freshwater interface to the high tide mark restricted the unsaturated zone available for recirculation, whereas in the dry season, this interface extended toward the low tide mark, enhancing recirculation and seawater mixing at the freshwater interface. This resulted in SGD enriched with recirculated water (up to 99%). Furthermore, ambient air temperature exerted a notable influence on the salinity in the STE up to 2 meters from the surface. Variations in physicochemical parameters across distinct zones within the STE, including the upper saline plume, seepage face, and saltwater wedge, delineated their boundaries. The influence of mixed semidiurnal tides on the proportion of fresh SGD and recirculated SGD was evident, with a marked increase in fresh SGD observed during spring tides. This study highlights the need for high-resolution monitoring to understand seasonal and tidal influences on STE dynamics, crucial for understanding coastal hydrology and biogeochemical cycles.