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Hydrogeochemical Dynamics of Middle Andaman: Unraveling the Impact of Seawater Intrusion and Limestone Caves on Groundwater Chemistry

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Abstract: Groundwater resources in coastal and island aquifers are increasingly threatened by seawater intrusion, exacerbated by climate change, sea level rise, erratic rainfall patterns, and over-extraction of groundwater. These challenges are particularly pronounced in Middle Andaman, where the interaction of groundwater, surface water, and seawater occurs within a complex hydrogeological framework. To assess the groundwater chemistry and its suitability for drinking and irrigation, a comprehensive study was conducted using geochemical, geospatial, and statistical methods.

Groundwater samples (n=24) and a reference seawater sample were analyzed for major ionic compositions using ICP, spectrophotometry, and flame photometry. Hydrogeochemical indices, including Chloro-Alkaline Indices (CAI), Water Quality Index (WQI), and agricultural suitability indices such as total hardness (TH), residual sodium carbonate (RSC), and magnesium adsorption ratio (MAR), were evaluated. A combination of ionic ratios—Cl/HCO□, Ca/(HCO□ + SO□), (Ca + Mg)/Cl, Ca/Mg, and others—was used to characterize the influence of seawater intrusion and the dissolution of limestone minerals in the aquifers.

The results revealed that 24% of groundwater samples were unsuitable for drinking based on WQI, while 80% and 12% of samples were unsuitable for irrigation based on TH and MAR, respectively. The Durov plot and Schoeller's diagram indicated a dominance of Ca-HCO□ and Na-HCO□ water

types in 48% and 24% of the samples, respectively, with enrichment of alkali and alkaline earth metal salts due to seawater intrusion. Chloride ion relationships suggested a reverse ion exchange process in 64% of samples, while X-ray diffraction analysis confirmed the presence of limestone minerals such as aragonite, calcite, dolomite, and magnetite.

Geospatial integration of hydrochemical data showed that 44% of the region was moderately affected, and 54% was slightly affected by salinity. Active tectonic lineaments and interconnected faults were found to facilitate seawater intrusion into the deep aquifer, highlighting the role of structural geology in the region's hydrogeochemical dynamics. This study underscores the urgent need for sustainable water resource management strategies to mitigate the adverse impacts of seawater intrusion on groundwater quality in Middle Andaman.

Keywords: Middle Andaman; Groundwater; Seawater intrusion; Water quality Index; Limestone caves