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Dilution of highly evaporated Dead Sea brines due to condensation and dissolution of hydrated minerals at near brine-air equilibrium

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The Dead Sea negative water budget together with low average annual regional relative humidity (RH<50%) is causing the lake level to drop rapidly and may push the brine toward hydrated chloride mineral saturation and precipitation. While past geochemical models focused on the Dead Sea evaporation, there has been little investigation to how brine composition will respond to temperature and humidity fluctuations once near-equilibrium is reached. To address this, we carried out preliminary natural evaporation field experiments on a series of brines from 02/2025 to 11/2025 at a hyperarid Dead Sea beach, and monitored the local climate, and brine geochemical and physical parameters.

From late winter to late spring/early summer (May/June) the brines' most conservative element, Li^+, concentrated monotonically, while densities rose from 1.25 to 1.40 kg L^{-1}. Evaporation of the brines was enhanced due to daytime heating of the evaporating brines in experimental beakers that were exposed to direct solar radiation. The water activity ($\alpha(H_2O)$) showed a continuous decrease from ~0.6 to 0.3, approaching the bi-weekly mean calculated relative humidity (RH) in the experimental beaker at the temperature of the surface water (ST), i.e., $\alpha(H_2O) \approx RH_{ST}/100$. Various X/Li concentration ratios reveal the chloride-evaporite sequence of halite (NaCl), carnallite ($KMgCl_3 \cdot 6H_2O$) and bischofite ($MgCl_2 \cdot 6H_2O$) precipitation. After $\alpha(H_2O)$ approached mean RH_{ST} (ca. June) and water loss changes became insignificant, relatively significant brine density decreases and dilution of dissolved Li^+ concentrations were observed in the following months. Based on ions' mass balance calculations, we interpret this reversal as a combination of condensation of atmospheric water onto the brine surface and dissolution of previously precipitated bischofite that released hydration water back into the brine H_2O reservoir. This study shows that significant geochemical and physical changes can occur in brines that precipitate hydrated chloride minerals at near unchanging water level.