

Paleo-hydroclimate signals and novel noble gas applications in deep groundwater systems: Case studies from the arid southeastern Mediterranean

JAKOB K. BRINKMANN¹, KERSTIN L. URBACH¹, ROI RAM^{1,2}, ALAN M. SELTZER³, ITAY J. REZNIK², WEI JIANG⁴, ZHENG-TIAN LU⁴ AND WERNER AESCHBACH¹

¹Institute of Environmental Physics, Heidelberg University

²Geological Survey of Israel

³Woods Hole Oceanographic Institution

⁴University of Science and Technology of China

Noble gases (NG) have been widely applied in groundwater systems to explore paleo-hydroclimate, enabling the determination of formation conditions and noble gas temperatures (NGTs) [1]. Beyond these ‘traditional’ NG applications, recent progress in heavy stable NG (Ar, Kr and Xe) isotope ratio measurements now potentially allows the reconstruction of paleo-water table depths (paleo-WTD), based on depth dependent fractionation in the unsaturated zone [2–4]. In theory, such effects should be substantial in deep groundwater systems (tens-of-meters WTD or more) and result in significant deviation from the atmospheric-derived composition, both in the NG bulk concentrations and the stable NG isotope ratios. These analytical developments expand and improve the NG toolset by introducing a window into unsaturated zone processes, which have been mostly neglected in previous NG-based hydrological studies.

This study examines the application of these novel NG tracers, alongside radiometric dating tracers and bulk NGs, in two distinctive groundwater systems in the arid southeastern Mediterranean. Groundwater in a local unconfined clastic aquifer, dated to the last-glacial, records recharge temperatures (NGTs) of ~23 °C and shallow paleo-WTD of ~5–15 m, relative to modern (pre-pumping) ~10–30 m WTD. In contrast, groundwater in a confined regional aquifer, is characterized by ~600 m deep current WTD below the recharge area. This groundwater shows large ranges in ⁸¹Kr ages (up to ~350 kyrs) and NGTs, along extreme neon excess (Δ Ne). A new finding is the correlation of Ar ratios with Δ Ne. The correlation is weaker for Kr and insignificant for Xe isotope ratios. By extending groundwater recharge models to include these NG isotope ratios, we find that the relationships between the isotope ratios and Δ Ne closely follows theoretical expectations for excess air under the closed-system equilibration (CE) model. While modeling and observations for the confined aquifer raise new questions concerning additional processes, the fractionation inclusive model fits well to the data from the clastic aquifer.

[1] Aeschbach-Hertig *et al.* (2000), *Nature* 405, 1040–1044.

[2] Seltzer *et al.* (2017), *Water Resources Research* 53(4), 2716–2732.

[3] Seltzer *et al.* (2019), *Earth and Planetary Science Letters*