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Groundwater mean transit times, mixing and flow paths evolution in faulted-hydraulic drop aquifer systems using chlorofluorocarbons (CFCs) and radioisotopes (3H & 14C)

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Environmental tracers (CFCs, 3H, 14C, 87Sr/86Sr, δ2H, δ18O) and geochemistry of various waters were used to assist our understanding of groundwater mean transit times (MTTs), mixing and flow paths evolution in faulted-hydraulic drop aquifer systems in the Manas River Basin (MRB), a typical mountain–oasis–desert ecosystem in the arid northwest China. The 3H activities were found to decrease with distance to the mountain from 41.1-60 tritium units (TUs) in the Manas River upstream groundwater (UG), south of the fault, to as low as 1.1 TU in the downstream groundwater (DG), north of the fault. Carbon-14 groundwater ages increased with distance from the midstream groundwater (MG, 3,000-5,000 years) to DG (>7,000 years). Deeper groundwater with older 14C ages has more depleted δ18O values than younger, which is consistent with it being derived from paleometeoric precipitation recharge. MTTs determined by CFCs and 3H are $\sim$20 years in the UG and between 30 and more than 105 years in the MG and DG.

Stable isotopes reflect a meteoric origin and little evaporation or isotope exchanges between groundwater and rock and soil minerals. Groundwater δ2H and δ18O values show more homogenized values along the groundwater flow paths and with well depth, as well as the homogeneous 87Sr/86Sr ratios, indicating inter-aquifer mixing progresses. The fault was found to play a paramount role on groundwater flow paths evolution, where local groundwater flow system is in the south of the fault and intermediate and regional groundwater flow systems are in the north of the fault. Lateral flow mixing and local groundwater flow system with groundwater ages between 25 and 52$\pm$2 years are delineated in the upstream area. Leaching and vertical mixing in the intermediate and regional groundwater flow systems corresponding to the longer flow paths and transit times (between 29 and 10,127 years) are delineated from the midstream to downstream areas. Three regimes are identified from the local to intermediate groundwater flow systems based on the CFC binary mixing model. 1) Recharge zone with fraction of 91-100% young water (groundwater ages of 25-29 years) is from the south mountain to the Shihezi (SHZ) west. 2) Discharge zone is characterized by a mixing fraction of 45-89% young water (29.6-40.4 years) in the SHZ north to the piedmont oasis plain. 3) Stagnant zone with fraction of 12-64% young water (36.2-52.7 years) is in the SHZ east and Manas River east.