

Deciphering complex groundwater age distributions and recharge processes in a tropical and fractured volcanic aquifer system

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September 25, 2021

Abstract

Groundwater recharge in highly-fractured volcanic aquifers remains poorly understood in the humid tropics, whereby rapid demographic growth and unregulated land use change are resulting in extensive surface water pollution and a large dependency on groundwater extraction. Here we present a multi-tracer approach including $\delta^{18}\text{O}$ - $\delta^2\text{H}$, $^3\text{H}/^3\text{He}$, and noble gases within the most prominent multi-aquifer system of central Costa Rica, with the objective to assess dominant groundwater recharge characteristics and age distributions. We sampled wells and large springs across an elevation gradient from 868 to 2,421 m asl. Our results suggest relatively young apparent ages ranging from 0.0 ± 3.2 up to 76.6 ± 9.9 years. Helium isotopes R/RA (0.99 to 5.4) indicate a dominant signal from the upper mantle across the aquifer. Potential recharge elevations ranged from ~1,400 to 2,650 m asl, with recharge temperatures varying from ~11°C to 19°C with a mean value of $14.5 \pm 1.9^\circ\text{C}$. Recharge estimates ranged from 129 ± 78 to $1,605 \pm 196$ mm/yr with a mean value of 642 ± 117 mm/yr, representing $20.1 \pm 4.0\%$ of the total mean annual rainfall as effective recharge. The shallow unconfined aquifer is characterised by young and rapidly infiltrating waters, whereas the deeper aquifer units have relatively older waters. These results are intended to guide the delineation and mapping of critical recharge areas in mountain headwaters to enhance water security and sustainability in the most important headwater dependent systems of Costa Rica.

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