Multi-tracer approach to constraining groundwater age structure

JT KULONGOSKI[1,2], B JURGENS[1], J ZAPPALA[3], P MUELLER[3], EK MACE[4], CE AALSETH[4], SK WHITE[4], P HUMBLE[4], K BELITZ[5]

[1]USGS, California Water Science Center, CA, USA
[2]Scripps Insitution of Oceanography, UCSD, La Jolla, CA
[3]Argonne National Lab, Argonne, IL, USA
[4]Pacific Northwest National Lab, Richland, WA, USA
[5]USGS, Water Mission Area, Reston, VA, USA

To assess trends in water quality, four wells near Fresno, California, were sampled multiple times between 2013 and 2019 for a suite of dissolved noble gases, isotopes, organic and inorganic constituents. The noble-gas chronometers krypton-85 (^{85}Kr), krypton-81 (^{81}Kr), argon-39 (^{39}Ar), and helium-4 (^{4}He), as well as tritium (^{3}H), sulfur hexafluoride (SF_6), and carbon-14 (^{14}C) were measured from two long-screened supply wells, one shallow and one deep, and two short-screened monitoring wells, one shallow and one deep, to better constrain groundwater age structure and flow velocities. While ^{85}Kr, ^{3}H, and SF_6 are frequently measured to constrain water recharged after 1950, the combination of ^{81}Kr, ^{14}C, and ^{39}Ar were used to identify more complex mixtures of groundwater recharged before 1950. These tracers also provide information on how fluids and gases move through the shallow crust.

Initial measurements of ^{14}C and ^{3}H indicated the age of groundwater in the shallow and deep supply wells was about 3,300 and 6,500 years, respectively. Subsequent measurements of ^{81}Kr and ^{39}Ar showed that water from the deep supply well had about 25% modern argon, and 100% modern ^{81}Kr, while the deep monitoring well had ~99% modern ^{81}Kr. Lumped parameter modeling showed that ^{14}C concentrations were not consistent with a single mixture of groundwater older than 100 years and that geochemical corrections of ^{14}C from dead-carbon sources alone could not explain the difference in measured ^{14}C, and ^{81}Kr and ^{39}Ar. Consequently, the distribution of groundwater age from the supply wells clearly indicates a binary mixture of water less than 1,000 years and water up to 10,000 years. ^{85}Kr, SF_6, and ^{3}H-^{3}He ages for the shallow monitoring and supply wells generally agreed, with ages between ~20 and 60 years. Iterations of models using these age-tracer data provide a means of evaluating the stability of apparent groundwater ages and which tracers are most appropriate to monitor groundwater quality change over seasonal, annual, and decadal timescales.