Applications of Isotope and Noble Gas Analyses for Water Resources Management

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In the US, 306 billion gallons of fresh water are withdrawn annually from either groundwater or surface water, for domestic use, agriculture, industry or energy production. The relative importance of these sources varies by state, from 80% groundwater reliance in Kansas, to 97% surface water reliance in West Virginia.

Groundwater is a stable, but finite resource. Overdraft threatens groundwater resources if extraction rates exceed recharge. Noble gas and isotopic signatures in groundwater can reveal the recharge mechanisms and conditions. The threats of contamination of groundwater by agricultural land use or point sources can be evaluated from groundwater travel times determined by tritium-helium or other age tracers. A geostatistical analysis of nearly 4000 tritium-helium ages and noble gas concentrations analyzed at LLNL showed that recharge in southern California is dominated by river bank filtration, irrigation return flow, and managed aquifer recharge. Areas of young groundwater coincide with Hydrologically Vulnerable Areas, as independently determined by the State Water Boards.

Although surface water is annually renewed, its availability is seasonally variable and uncertain due to future climate and environmental change. An enhanced understanding of the response and subsurface storage of headwater catchments through water residence-time studies can improve drought-vulnerability assessments. Preliminary results of tritium analyses at the Southern Sierra Critical Zone Observatory show a disconnect between stream water and vegetation uptake in August. Streams discharge decade-old water, while plants transpire recent summer precipitation.

“Banking” surface water in subsurface reservoirs provides an economical opportunity to increase the reliability of water supply. The application of water banking has been limited by a lack of knowledge of groundwater/surface-water interactions, recovery efficiency, and water quality concerns. Water recovery efficiency was studied at an Aquifer Storage and Recovery (ASR) well in Woodland (CA) using introduced xenon as a tracer. In this case, 95% of the xenon was recovered after extraction of three injection volumes. Xenon samples were analyzed on a LLNL-developed benchtop Noble Gas Membrane Inlet Mass Spectrometer (NG-MIMS), greatly reducing the cost and turnaround time compared to traditional noble gas mass spectrometry. An introduced xenon tracer experiment at an artificial recharge pond in Fremont (CA) demonstrated the subsurface travel time towards a drinking water production well met the public health criteria. These and other examples demonstrate the benefit of isotope and noble gas tracer studies for water resources research and management.

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