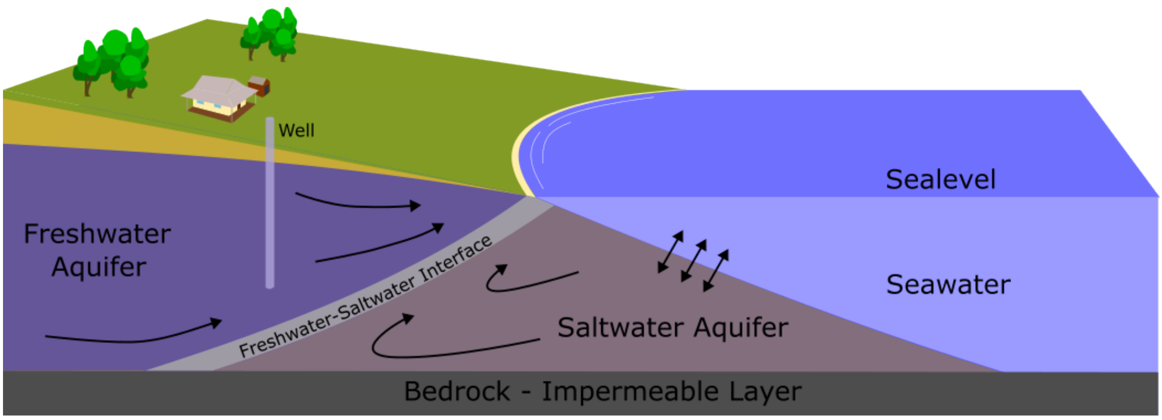
THE UNIVERSITY *of* ADELAIDE

RADIOACTIVE NOBLE GAS TRACERS: APPLICATION IN COASTAL AQUIFERS

Coastal groundwater aquifers are used globally as a primary source of fresh water. In Australia, over 85% of the population live in coastal areas and are impacted by the health of coastal aquifers. They are important for town and domestic water supplies, irrigation of crops and pastures and for industrial processes. However, human activities such as excessive freshwater pumping can disrupt the natural dynamics of the system, inducing the flow of saline sea water into inland freshwater aquifers. This happens when a decrease in the groundwater level shifts the saltwater wedge underlying the freshwater aquifer inland, causing salinisation of vast areas, impacting communities and ecosystems. Worryingly, saltwater intrusion may occur over long time scales and go undetected for an extended time. It is therefore pivotal to improve our understanding of risks to coastal aquifers by strengthening monitoring practices using groundwater tracers.

Coastal aquifers are also impacted by pollution from industrial and agricultural practices where surface runoff containing dissolved chemicals can infiltrate the groundwater. Understanding the subsequent flux of chemicals, that move via the groundwater into the ocean or into river systems, is therefore critical to determine further pollution evolution and whether water quality thresholds will be exceeded.

Direct measurement of the seawater intrusion rates and groundwater fluxes using traditional residence time tracers like ^{14}C and ^{36}Cl is complicated because the interpretation of results is affected by water-rock interactions. Seawater intrusion also enhances solubility of carbonates which disturbs the information from ^{14}C, and in the mixing zone the ^{36}Cl information is overprinted by salt water. The noble gas radioisotopes ^{85}Kr, ^{81}Kr, and ^{39}Ar are the most robust age indicators in this context and can be measured using the state-of-the-art technique Atom Trap Trace Analysis (ATTA).



Applications of ^{85}Kr, ^{39}Ar, and ^{81}Kr

The noble gas radioisotopes are ideal tracers of groundwater movement, they are chemically inert and provide the most reliable assessment of groundwater residence time. Krypton-85 (half-life 10.7 years) is most suitable for short-term hydrological process of decades; argon-39 (half-life 269 years) is the only tracer for groundwater residence times on the century timescale; and krypton-81 (half-life 229,000 years) is a near-ideal tracer to characterize ancient groundwater. Applications can include:

• Identifying hydraulic connectivity between aquifers and the sea and **vulnerability** of aquifers to **over pumping** and **sea level rise**.

• Distinguishing recent **seawater intrusions** from ancient seawater intrusions (e.g. during the mid-holocene when sea levels were 1.5m higher in Eastern Australia).

• Identification of old groundwater resources that may replenish only under **different climatic conditions**.

• Constrain residence time distributions and **mixing** between young and old groundwater.

• Assessment of freshwater/saltwater **circulation dynamics** directly in the mixing zone where conventional tracers such as ^{14}C and ^{36}Cl fail.

• Identification of infiltration conditions and **past climate** in combination with other tracers (e.g. stable noble gases).

• Discrimination between different **recharge** sources.

• Provide reliable **input data** for calibration and verification of numerical models.

• Constrain the transport and fate of **pollutants** and **excess nutrients** from freshwater aquifers into ocean water.

Complicated systems

Coastal aquifers are unique in that they are characterised by the hydraulic interaction of saline sea water and local freshwater aquifers. Sea water intrusion generally occurs by shifting the freshwater-saltwater interface which can be the result of human activity, but can also occur by vertical infiltration during and after ocean surges. Saltwater intrusion may occur over long time scales, not be directly observed due to lack of observation wells, but may affect aquifers in the long term. In dual porosity aquifers, saltwater initially intrudes mainly in the mobile areas, while transfer into stagnant areas is a slower process. Once freshwater flow is re-established, salt will continue to leach from the stagnant zones causing salt levels to remain high even in the mobile areas. Intrusion processes depend on sea level, pump rates and recharge rates in the aquifer and either natural or anthropogenic variations can shift the freshwater-saltwater interface. Noble gas radioisotopes are well-suited to improve insights into such complicated systems.

The Australian ATTA facility

The University of Adelaide and CSIRO operate a joint sovereign facility for measuring stable and radioactive noble gases in the environment. Samples can be collected from water, the atmosphere, or ice and analysed at our facility. Gas is extracted and purified at the CSIRO Waite campus in Adelaide and measured for ^{85}Kr and ^{81}Kr at the University of Adelaide ATTA facility. The facility is one of only four locations on the globe that offers measurement using the ATTA technique and is the only facility in the southern hemisphere offering this service.

FOR FURTHER ENQUIRIES:

THE INSTITUTE FOR PHOTONICS AND ADVANCED SENSING
rohan.glover@adelaide.edu.au +61 (0)8 8313 3684
OR ipasadelaide@adelaide.edu.au +61(0)8 8313 9211

CSIRO ENVIRONMENT
dirk.mallants@csiro.au +61 (0)8 8303 8530