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Multi-Tracing Groundwater Flow through a Karst Aquifer in South West Ireland using Dissolved Krypton, Rhodamine WT and Bromide.

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A multi-tracer test using dissolved krypton (Kr), rhodamine WT (RWT) and bromide (Br) has been conducted in a karst system in South West Ireland to prove hydraulic connection(s) and characterise travel times and solute transport characteristics for the subsurface portion of a river reach submerging underground (the ingress point) and emerging at two presumed discharge (egress) points some 0.5km away (egress#1: a turlough or seasonal 'vanishing lake'; egress#2: the emerging river reach). The lithology consists of the Burren Limestones, essentially a pure limestone with a microporous primary matrix porosity but with solute transport typically affected by karst features, eg. a dominating secondary porosity such as conduits, regionally this forms an important aquifer characterised generally by shallow till cover with prevalent outcropping bedrock. This type of system is therefore susceptible and vulnerable to surface pollution. Tracers were selected to provide confirmatory or complementary characterisation of the subsurface, and the tracer mix delivered simultaneously at the injection (ingress) point. Br^- was chosen as conservative "gold standard" tracer. RWT also potentially acts as a conservative tracer but provided a larger dynamic range of use; it was suspected however that retardation could occur if appreciable organic matter was in fact in the system and in that case RWT might used as an analogue tracer for other dissolved organic compounds. In pristine, saturated systems dissolved Kr will also act as a conservative tracer, but if the subsurface system is not fully saturated then Kr becomes a partitioning tracer between gas and water phases. As a dissolved gas, Kr was

also chosen as an analogue tracer for volatile organic compounds (VOC) behaviour. Breakthrough curve (BTC) analyses showed that the Br^- tracer was effectively diluted to background concentration and not detected. Both mean and first breakthrough transit times for Kr and RWT are similar, which shows that the subsurface system is fully saturated. Apparent tailing of the BTC data for both tracers likely reflects a degree of diffusive exchange of tracer solutes with matrix pore waters and a degree of solute storage and retardation in the subsurface system. Mean linear transit velocities of $\sim$190m/hr (egress #1) and $\sim$160 m/hr (egress#2) were calculated for the traced system strongly suggesting conduit flow and proving a direct linkage between with both discharge points.