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Field-Scale Multi-Barrier Experimental System for In-Situ Geochemical Investigation of Radionuclide Migration at KAERI Underground Research Tunnel

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Understanding radionuclide release from engineered barriers and subsequent migration into the surrounding host rock is essential for evaluating the long-term behavior of deep geological repositories. While laboratory experiments have provided insight into barrier materials and radionuclide behavior, field-scale validation under repository-relevant hydrogeochemical conditions remains limited. In this study, we established a field-scale multi-barrier experimental system at the KAERI Underground Research Tunnel (KURT) to investigate radionuclide migration across engineered and natural barriers under undisturbed hydrogeological conditions.

Detailed site characterization using borehole imaging and hydraulic testing identified a low-dip fracture zone at 6.5–7.5 m depth with measurable connectivity. Based on this characterization, an integrated experimental framework was developed that combines (i) an *in-situ* groundwater monitoring system at fracture depth and (ii) a field-deployable multi-barrier analog module incorporating a bentonite-filled core to simulate engineered barrier conditions and introduce tracers under controlled, low-flux conditions.

Despite relatively high hydraulic conductivities (10^{-7}–10^{-4} m s^{-1}), low natural gradients indicate that transport is flux-limited. Under these conditions, conservative and reactive tracers (Cl, I, D_2O, Cs, Sr), used as radionuclide analogs, will be introduced at controlled rates to evaluate coupled advection, diffusion, and sorption processes. This installation provides a practical field-based platform for investigating radionuclide migration across engineered and natural barriers under repository-relevant conditions.