Preliminary Tracer Tests at the Inclined Boreholes of Fractured Rock in KURT

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1. Introduction

Numerous laboratory and field-scale studies worldwide have been explored the behavior of radionuclides in disposal environments [1-4]. There is a particular emphasis on the importance of securing essential technical information and input data through field studies to comprehend the heterogeneity and complexity of natural environments [3-5]. In our study, we conducted a preliminary *in-situ* tracer experiment using non-radioactive nuclides at KURT (KAERI underground research tunnel) in Korea. The aim of this experiment was to acquire fundamental data for simulating multi-barrier disposal environments in the future.

2. Methods and Results

2.1 Location and Geology of the Study Area

The research facilities were located in KURT, situated in the northwestern region of Daejeon, Korea. The geology of this study area is primarily the Jurassic granite from the Mesozoic Era, predominantly composed of two mica granite and biotite granite. The three fracture zones have been identified around KURT, two of which are closely situated and exhibit similar slopes, leading them to be regarded as a single fracture zone from a hydrogeological perspective. This combined fracture zone, known as MWCF (main water conducting fractures), is anticipated to serve as the principal conduit for groundwater flow in the vicinity of KURT.

2.2 Boreholes and Multi-Packer Monitoring

The five boreholes (RD-1 to RD-5) were drilled within the MWCF fracture zone and utilized for the preliminary tracer experiments (Fig. 1). These boreholes, inclined at a 20° slope, were excavated on the tunnel wall, with each drilling hole having a diameter of 3 inches and reaching depths of 10-15 meters. The central drilling hole, RD-3, is positioned approximately 1.2 meters from the bottom surface of KURT, with an interval of about 1 meter between each drilling hole.

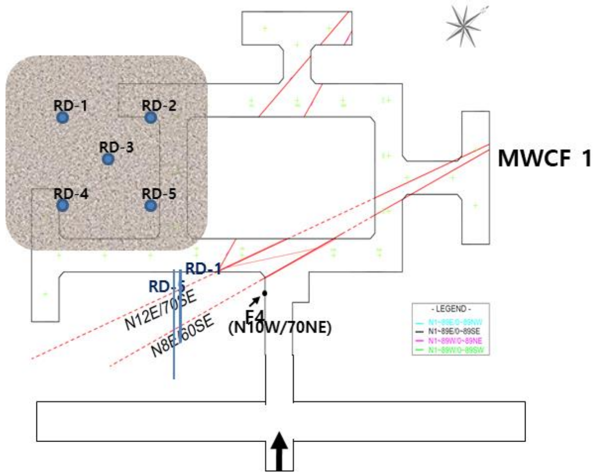

Fig. 1. Location of the inclined boreholes for the preliminary tracer experiments

Upon examining the fracture distribution within the borehole, a notable increase in frequency was observed, particularly within the depth range of 3-7 meters. In accordance with the observed frequency data, the borehole was partitioned into sections and isolated using a multi-packer monitoring system (Table I). This approach sought to identify groundwater flow within the highly fractured section, verify the connectivity between each borehole, and evaluate the possibility of migration to other fracture sections.

Table I. Isolation section of the inclined boreholes using multi-packer monitoring system

Borehole	Section 1 (m)	Section 2 (m)	Section 3 (m)
RD-1	0.00 ~ 3.03	3.03 - 6.89	6.89 - 9.69
RD-2	0.00 ~ 3.33	3.33 - 7.19	7.19 - 9.88
RD-3	0.00 ~ 3.40	3.40 - 7.24	7.24 - 9.83
RD-4	0.00 ~ 3.48	3.48 - 7.36	7.36 - 9.95
RD-5	0.00 ~ 3.80	3.80 - 7.76	7.76 - 15.34

2.3 Hydraulic Tests

The hydraulic tests were performed through natural discharge and constant head injection tests to identify the connectivity of the fractures of each borehole and to evaluate the capability of the preliminary tracer test. Two natural discharge tests have shown a decrease in discharge flow rate in most sections due to the changes in weather conditions, but the difference was not significant. The results of the constant head injection test suggested the hydraulic conductivity of this fracture zone ranged from 3×10^{-8} to 7×10^{-7} m/s.

2.4 Preliminary Tracer Experiments

Five representative non-radioactive nuclides (i.e., Cl, I, Cs, Sr, Ni) were injected into the central borehole (RD-3) at a flow rate of 21.0 mL/min. Their movement through the fracture zone was monitored using breakthrough curve (BTC) analysis. Interestingly, the BTC results for this preliminary tracer experiment deviated from the typical laboratory-scale pattern, possibly due to the presence of multiple fractures rather than a single one. While non-sorbing ions (Cl and I) were transported along the groundwater flow, the transport of other sorbing ions was relatively impeded within the fracture zone.

3. Conclusions

This study aimed to deepen our understanding of nuclide behavior within the fracture zones of granite rocks, simulating the disposal environments. Although the results of this preliminary *in-situ* experiment lacked the necessary data for quantitative assessment of major nuclide behavior in the KURT environment, they provided qualitative data on the behavior patterns of various nuclides under field conditions. This data will be utilized for the future field tests to simulate the multi-barrier disposal environments.

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