Draft of Regulatory requirements for site characterization using site-specific underground research facility

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1. Introduction

The requirements 2 and 11 in the IAEA SSR-5 provide a requirements for site evaluation for repository facility of high-level radioactive waste. In order to meet the contents in the requirement, detailed site geological evaluation is essential. Since site geological characteristics are vary depending on depths and locations, using site specific URF (Underground Research Facility) is thus recommended as a good way to evaluate site characteristics.

The site evaluation work using URF is not common in Korea and regulatory requirement is not sufficient to meet the requirements of the IAEA. Therefore, previous research works using URFs are summarized, and regulatory requirement are suggested.

2. Constraint criteria of the URFs, and the experiments

Since Pre-Salt Vault (1959, USA), there have been more than 30 URFs constructed, and more than 10 of the currently operating URFs are hosted in various rock types. Among which Grimsel (Switzerland), Äspö (Sweden), ONKALO (Finland), Mizunami (Japan) and Bukov (Czech) are in crystalline host rock, and Mont Terri (Switzerland) and Horonobe (Japan) are in argillaceous host rock.

Among currently operating UFRs, three research facilities are selected: Bukov, Czech; Äspö, Sweden; Mont Terri, Switzerland considering kinds of experiments and availability of data and so on. Their experimental work are analyzed. They conduct a lots of experiments, so specific experiments are used in analysis based on related IAEA requirements such as SSR-5 and SSG-14.

3. Results of the case studies

3.1 Summary of the representative URFs

First, Bukov [3, 4] is a URF project of Czech Republic launched by SURAO, the radioactive waste repository authority, and its contractor DIAMO, an organization dealing with the elimination of consequences in mining activities. This URF is located at a depth of about 600 m under the surface in which the geology is mainly composed of crystalline rocks such as gneiss, migmatite, and granulite. Its goal is characterization of the following subjects in the specific geological condition and depth range in order for it to be used as a potential site of a DGR for radioactive waste: (1) Spent nuclear fuel and other high level waste form behavior under DGR conditions, (2) Spent nuclear fuel and high level waste material container behavior under DGR conditions, (3) Behavior of buffer, backfill and other construction materials under DGR conditions, (4) Construction of disposal holes and their influence on surrounding rock properties, (5) Rock massif behavior, (6) Radionuclide transport from DGR, (7) Other site characteristics potentially influencing DGR safety.

Second, Äspö Hard Rock Laboratory [3, 5] is a URF operated by SKB, a Swedish nuclear fuel and waste management company, and is located at a depth of 460 m under the surface in crystalline host rock mainly composed of granite. The original purposes of this URF were to verify pre-investigation methods, finalize detailed investigation methodology, test models for description of the barrier functions at natural conditions, demonstrate construction and handling methods, and test important parts of the repository system. Currently it is being operated to achieve the following additional purposes: refine and verify the methods and technologies for the characterization of the rock; develop, test, evaluate and demonstrate methods for repository design and construction; develop and test alternative technology; increase scientific understanding and provide data for the long-term safety assessment; provide experience and train personnel; provide information to the public on technology and methods; and participate in international co-operation. The selected experiments conducted in the URF are divided into the following 10 areas: (1) Pre-excavation characterization activities, (2) Characterization activities during excavation, (3) Experiments to characterize the fundamental properties and behavior of host rocks, (4) Assessment and testing of instrumentation, sampling, and monitoring techniques, (5) Development and testing of instrumentation, sampling and monitoring techniques, (6) Disposal concept demonstrations, (7) Experiments to characterize the effects of construction and excavation on host rocks, (8) Experiments to characterize the behaviors and performance of engineered barrier system components, (9) Experiments to demonstrate aspects of repository operations, (10) Experiments to understand near field interactions between disposal system components.

Third, Mont Terri Rock Laboratory [3, 6] is a URF in Switzerland operated by Swisstopo, the federal office of topography of Switzerland, and is located at a depth of

about 300 m under the surface in argillaceous host rock mainly composed of opalinus clay. The purposes of this URF are research and development, characterization of the opalinus clay, and optimization of engineered barrier systems. The basic aims of the experiments in this URF are (1) understanding the characteristics, processes, and mechanisms in undisturbed claystones, (2) understanding the repository-induced perturbations, and (3) performing experiments related to the demonstration of repository implementation technology.

3.2 Essential experiments

We assigned each of the subjects of the experiments into the seven types below to make certain that the experiments subjects listed are thorough and systematic, and to find the essential factors (Table 1).

R: characterization of the mechanical behaviors of the **R**ock (related to diffusion of radionuclides)
G: characterization of the features of the **G**roundwater (related to migration of radionuclides)
C: characterization of the geo**C**hemical states and processes
P: **P**erformance demonstration of the facility and materials
D: nature in DGR **D**epth
T: demonstration of long-**T**erm monitoring
Q: **Q**ualification of the tools and methodologies

Table 1. List of the experiments by representative URFs with types.

URF	Subjects of Experiments	Type
Bukov	Detailed geological and hydrogeological characterization of the underground	R, G
	Long-term hydrogeological monitoring	G, T
	Monitoring of changes in stress state and changes in behavior and character of underground working over time	T
	Monitoring of macro- and micro seismicity	T
	Displacement monitoring on faults	R, T
	Geophysical monitoring with focus on testing the methodologies for rock massif homogeneity verification in the vicinity of mine work	R, D, T
	Hydrodynamic tests in the boreholes	G
	Hydraulic model assessment	G
	Programme of migration/tracer tests	G
	Determination of groundwater age and origin	G
	Transport model testing	G
	Experiment of Mock-up type	M
	Testing of EDZ (Excavation damage zone) and EdZ (Engineered disturbed zone) formation and development in metamorphic rock in DGR depth	R, P, D, Q
Äspö	Site Investigations to Locate and Characterize the Host Rock of the Äspö Hard Rock Laboratory	R,
	Rock Visualization System (Modeling Tool Development)	R
	Blasting Damaging Experiment	R, P
	Passage of Water-Bearing Fracture Zone	R, G
	Block Scale REDOX Experiment	C
	Hydro Monitoring System (Development of Geoscientific Instruments and Methods)	G, T
	CHEMLAB Probe and Radionuclide Retention	G, C, Q
	Groundwater Sampling from very Low-Conductivity Rock (Development of Geoscientific Instruments and Methods)	G, C, T
	The Multiple-Well Tracer Experiment	G
	Prototype Repository Test	P
	Hydraulic Testing Methods at High Groundwater Pressures	G
	Zone of Excavation Disturbance Experiment	R, P, Q
	Fracture Classification and Characterization	R
	Tracer Retention Understanding Experiments	G
	Detailed Scale REDOX Experiment	C
	Underground Measurement Methods and Methodology	Q
	Mechanical Modelling of Cracks Caused by Mechanical Excavation	R, P, Q
	Hydrochemical Stability	G, C
	High-Permeability Features	R, G
	Colloid Project	G
	Rock Stress Measurements	R
	Heat Transport	R
	Fe-Oxides in Fractures	C
	Rock Shearing Experiment	R
	Geology–Rock Characterization System	R
Mont Terri	Petrofabric and Strain Determination	R
	Geophysical Characterization of EDZ	R, P, Q
	Rock Mass Characterization	R
	High Resolution Seismic Monitoring	T
	Nanoseismic Monitoring	T
	Seismic Transmission Measurement	R
	Pore Water Sampling and Characterization Experiments	G, Q
	Monitoring with Passive Geophysics	R, T
	Diffusion Experiments	G

	Self-Sealing of Tectonic Faults	R, D, T
	Fracture Generation	R

4. Conclusion

We reviewed the experiments for site characterization from three representative URFs to enact regulatory requirements for meeting the requirements of the IAEA. Based on results of the review, essential factors were extracted from the list of experiments. Using the factors, the following draft of Notice as regulatory requirements were made.

Article 0 ① The Objectives of site characterization through site specific underground research facilities shall include the following:

a. Identify the diffusion, migration, and reaction of radionuclides

b. Demonstrate the design performance of layout and materials

c. Predict the long term variation of site characterization, facilities, and materials

d. Characterization of natural and engineering barriers at the location and depth of actual disposal facilities

② Investigation under paragraph 1 shall include the following:

a. Surface geological condition and rock mass

b. Surface water (include precipitation) and groundwater

c. Fracture network and Fracture filling materials

d. Factors expected to have a significant effect on each of the subparagraphs of paragraph 1

Although we attempted to establish complete regulatory requirements in this Draft of Notice, it may subsequently be modified through further studies that include a wider array of cases. As for concerns over more detailed and suitable regulatory requirements for domestic geology, the further review of other appropriate URFs to ascertain level of standard review guides for a regulatory body is planned.

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