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Second Progress Report on Research and Development for TRU Waste Disposal in Japan

— Repository Design, Safety Assessment and Means of Implementation in the Generic Phase —

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Japan Atomic Energy Agency

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Chapter 1 Introduction

Nuclear fuel cycle policy in Japan calls for implementation of safe, reliable disposal measures for all categories of radioactive waste, including waste containing transuranic radionuclides (TRU waste) and high-level waste (HLW).

Against this background, Japan's reprocessing activities and the operation of its MOX fuel fabrication facilities, both of which produce TRU waste, will be reviewed in this report, taking into account results from relevant studies, technical data on treatment facilities for other types of radioactive waste and the state of development of the required institutional framework. Appropriate consideration is also given to the status of safety assessments and technological developments in foreign radioactive waste management programs.

This technical review of the disposal of TRU waste has been prepared as a collaborative effort of the electric power utilities, the Japan Nuclear Cycle Development Institute (JNC; since October 2005 the Japan Atomic Energy Agency) and other involved organizations. It updates the report entitled "Progress Report on the Disposal Concept for TRU Waste in Japan", which was published in 2000, and reflects the latest results of the research carried out by the utilities and JNC since the publication of this earlier report. The aim is to establish and demonstrate state-of-the-art technologies for the safe disposal of TRU waste.

1.1 Context of the report

1.1.1 Status of studies on TRU waste disposal in Japan

In March 2000, the electric power utilities and JNC published a summary document entitled "Progress Report on the Disposal Concept for TRU Waste in Japan" (1st TRU progress report; TRU Coordination Team, 2000). The report addressed the disposal of TRU waste arising from fuel reprocessing, MOX fuel fabrication and dismantling of nuclear facilities and the possibilities for disposing of this waste under representative geological conditions in Japan. It also highlighted technological issues to be addressed in future research and development programs.

Also in March 2000, the Advisory Committee on Nuclear Fuel Cycle Backend Policy of the Atomic Energy Commission of Japan referred to the 1st TRU progress report and studies on waste disposal methods carried out in Japan up to that time in preparing its summary report "Basic Concept for the Disposal of Radioactive Waste Containing Transuranic Radionuclides" (Advisory Committee Report; AEC, 2000a). The report discussed how, using criteria such as types and concentrations of radionuclides, this waste can be divided into three categories: that destined for disposal in shallow concrete vaults (shallow disposal), that for disposal below generally accessible depths (50-100 m; intermediate-depth disposal) and that suitable for deep geological disposal. The report also highlighted issues to be considered in future technical developments, as follows:

- In order to rationalize and refine disposal facility designs and build confidence in safety assessments, the following issues must be considered:
  - acquisition of relevant test data;
  - accurate understanding of key phenomena (for example alteration of cement, reactions between alkaline solutions/buffer material and the rock and the effects of nitrate and gas generation) and construction of assessment models taking these phenomena into account.

- Further research into improving the ability of the safety barriers to retain iodine.

- Development of a waste package database and quality management procedures and validation methods that will build confidence in the quality of waste package production.

The publication of the Advisory Committee Report was followed by a report of the Atomic Energy Commission entitled "On the Treatment and Disposal of Transuranic Radionuclide Bearing-Radioactive Waste" (AEC, 2000b). This states that the responsible authorities should take into consideration the findings in the Advisory Committee Report and, against this background, should cooperate in moving actively towards implementing disposal. The report also states that it is necessary to consider basic concepts for safety regulations and to establish safety standards and relevant legislation. It also highlights the importance of providing accurate and easily understandable information, while at the same time understanding the need to obtain feedback from concerned stakeholders, which is an important aspect of policy-making. The "Long-term Program for Development and Utilization of Nuclear Energy" (AEC, 2000c), which was revised in November 2000, presents issues that should be addressed by the waste producers in progressing towards implementation of radioactive waste disposal, including TRU waste. These issues are described below.

> "In the case of radioactive waste for which concrete disposal measures have not yet been decided, it is necessary, in order to ensure safe and efficient management from the beginning, for the waste producers to cooperate closely in developing proposed strategies.
> Besides high-level waste, there are other types of waste that require geological disposal. It is important that studies on disposal of these other wastes should make appropriate use of results from research on high-level waste disposal. It is also important to develop waste treatment and disposal technologies taking into account the diverse characteristics of these wastes."

Under the auspices of the Advisory Committee on Energy and Natural Resources, between October 2003 and January 2004 the cost structure for the entire back-end project was analyzed by a subcommittee of the electricity utilities, in preparation for the start of commercial operation of a reprocessing plant by Japan

Nuclear Fuel Limited (JNFL) (ANRE, 2004). The expected costs of TRU waste disposal were presented, based on estimates of the cost of a high-level waste repository.

The Atomic Energy Commission of Japan has developed fundamental concepts for disposal of all types of radioactive waste produced by the nuclear power plants. Safety principles that apply to disposal of all waste types have also been formulated by the International Atomic Energy Agency (IAEA, 1995). Based on these documents, a committee on atomic energy safety was set up to consider key regulatory and safety issues for all wastes ranging from low-level to high-level. The results of the deliberations are summarized in a report entitled “Common Important Issues for Safety Regulations of Radioactive Waste” (NSC, 2004).

The electricity utilities, JNC and responsible government agencies have pursued research and development that targets the key technical issues described in the 1st TRU progress report and the Advisory Committee Report. In particular, in their capacity as TRU waste producers, the utilities and JNC (now JAEA) will continue to cooperate on research and development aimed at refining and rationalizing the disposal concept, improving understanding of the particular phenomena associated with TRU waste disposal and enhancing confidence in safety assessment methods.

Table 1.1-1 presents the status of discussions and the development of safety regulations and standards for the various categories of radioactive waste.

Table 1.1-1 Status of discussions, safety regulations and safety standards for radioactive waste disposal (as of March 2005)

Waste classification			Atomic Energy Commission of Japan	Nuclear Safety Commission of Japan			Applicable laws and safety regulations		
			Basic disposal concept	Concept for safety regulation	Upper limit of concentration	Guidelines for safety review	Government decree	Regulation	Notification of technical details
High-level waste			Already evaluated (May 1998)	Already evaluated (November 2000)	-	Later consideration	To be formulated in future		
Low-level radioactive waste	Waste generated by nuclear facilities	Low-level waste with concentrations above those decreed by government	Already evaluated (October 1998)	Already evaluated (September 2000)	Already evaluated (September 2000)	Under consideration	Already established (December 2000)	To be formulated in future	To be formulated in future
		Homogeneous solid waste, miscellaneous solid waste, etc.	Already evaluated (August 1984)	Already evaluated (October 1985)	Already evaluated (February 1987, June 1992)	Already evaluated (March 1988)	Already established (March 1987, September 1992)	Already established (January 1988, September 1993)	Already established (January 1988, September 1993)
		Very low-level radioactive waste (VLLW) (concrete waste, etc.)			Already evaluated (June 1992)	Already evaluated (January 1993)	Already established (September 1992)	Already established (February 1993)	
		As above (VLLW) (metal etc. waste)			Already evaluated (September 2000)	Under consideration	Already established (December 2000)	Improvement in future	
	Radioactive waste including TRU		Already considered (April 2000)	Under consideration (June 2000～)	Later consideration	Later consideration	To be formulated in future		
	Uranium waste		Already evaluated (December 2000)	Later consideration	Later consideration	Later consideration	To be formulated in future		
	RI / laboratory waste		Already evaluated (June 1998)	Already evaluated (RI waste: January 2004) Under consideration (laboratory waste)	Later consideration	Later consideration	To be formulated in future		
No need to handle as radioactive waste	Clearance level		Already evaluated (August 1984)	Already evaluated (nuclear reactors: July 2001, facilities using nuclear fuel: April 2003) Under consideration (facility for RI) Later consideration (radioactive waste including TRU, uranium waste)			To be formulated in future		
	Clearance level validation			Already evaluated (nuclear reactors: July 2001 onwards) Later consideration (others)					

1.1.2 Objective of this report

In other countries with radioactive waste disposal programs, a stepwise or phased approach is adopted for research and development and for implementing disposal (e.g. OECD/NEA, 2004). At each stage, discussions are held and decisions made to provide appropriate input for the next step. At the same time, research institutions and other organizations provide input on key aspects of the long-term safety of disposal, to allow this to be reflected in the discussions and decision-making process. The current status of technological developments and technical issues remaining open are documented in integrated reports.

The following are examples of technical reports produced in stepwise investigation programs: the U.S. Department of Energy's EIS report for the Yucca Mountain Project (DOE, 2002); the Project Gewähr report series (Nagra, 1985), the Kristallin-1 report (Nagra, 1994) and the Entsorgungnachweis report (Nagra, 2002) in Switzerland; the SR-97 report of SKB, Sweden (SKB, 1999) and the "Dossier 2001" of ANDRA, France (ANDRA, 2001). In Japan, the 1st progress report H3 (PNC, 1992) and the 2nd progress report H12 (JNC, 2000) on geological disposal of high-level radioactive waste, the 1st TRU progress report and the present report (the 2nd TRU progress report) have all been produced in the context of a staged program.

Production of TRU waste from the operation of JNFL's commercial reprocessing plant will commence in the near future. In addition, the new organization established in October 2005 by the merger of the Japan Nuclear Cycle Development Institute and the Japan Atomic Energy Research Institute (Japan Atomic Energy Agency, JAEA) will be responsible for implementing environmentally acceptable disposal measures for TRU waste. The time is therefore right to evaluate the procedures for implementation, disposal and site selection and to move forward with establishment of safety standards and the institutional framework for regulating safety.

Against this background, the utilities and JNC prepared the 2nd TRU progress report. Based on the latest information on waste packages and projected waste characteristics, the report presents a refined geological disposal concept for TRU waste, with the aim of improving confidence in the safety of disposal in a wide range of geological environments in Japan. To allow integration of the latest results of relevant research, the cooperation of the Central Research Institute of the Electric Power Industry (CRIEPI) and the Radioactive Waste Management Funding and Research Center (RWMC) was obtained.

A drafting team was set up to bring together all the relevant work and to prepare the final report. Three sub-working groups (SWG) were also established: a database SWG to prepare a database of waste characteristics and nuclide migration data, a disposal technology SWG for developing and refining the disposal facility design and a performance assessment SWG for evaluating the safety of the engineered and natural barriers. The report was prepared through active cooperation between these groups (cf. Appendix 1A).

1.1.3 Approach to preparing the 2nd TRU progress report

In preparing the 2nd TRU progress report, the technology development tasks identified in the Advisory Committee Report and the 1st TRU progress report were addressed. Information on disposal concepts and the safety of each potential disposal system - deep geological disposal, shallow disposal and intermediate-depth disposal - was based on the updated waste database, which reflects the results of the latest research and development and state-of-the-art waste treatment methods. In the 2nd TRU progress report, each disposal concept is evaluated by considering possibilities for improving repository operation and safety regulations. Activities such as site selection are not evaluated and a review of safety regulations and standards is presently being carried out. These activities can be regarded as part of the generic research and development stage and take into account a wide range of geological conditions.

The 2nd TRU progress report takes into account the data, mass transport models and safety assessment scenarios that were applied for a wide range of geological environments in the H12 report on HLW disposal, and which are based on the disposal concept described in the 1st TRU progress report. The details of the disposal concept are presented, together with a comprehensive safety assessment and supporting arguments.

In view of concepts being considered in other countries, an evaluation of co-disposal of high-level waste at the same site as TRU waste highlights approaches for preventing mutual interference between the two disposal facilities. The evaluation concludes that, for established disposal methods, mutual adverse influences can be ruled out.

A report entitled "Reference Radionuclide Concentration Values for Low-level Radioactive Solid Waste to be Land Disposed" (NSC, 1986) considered a shallow (concrete vault) disposal system for low-level radioactive waste generated by nuclear power plants; applicable laws and safety regulations have already been developed and implemented. JNFL is presently carrying out shallow disposal of low-level waste at Rokkasho village in Aomori Prefecture.

In the 2nd TRU progress report, waste containing alpha nuclides destined for concrete vault (shallow) disposal is distinguished using its upper radionuclide concentration limit, in accordance with the law on regulation of nuclear fuel/nuclear fuel material and nuclear reactors. A review was carried out, based on the disposal concept and safety assessment presented in the 1st TRU progress report.

For the intermediate-depth disposal system, a report on disposal of low-level waste generated by nuclear reactors with upper concentration limits that exceed current legal limits (AEC, 1998) considers the concept for a disposal facility and for ensuring safety during and after the management period for this waste. The law on the regulation of nuclear fuel/nuclear fuel material and nuclear reactors mentioned above has been revised based on a document entitled “Reference Radionuclide Concentration Values for Low-level Radioactive Solid Waste to be Land Disposed (3rd Interim Report)” (NSC, 2000a). The upper concentration limit for waste generated from nuclear reactors was also based on the safety standards in this report. Additionally, a report on safety regulation of radioactive waste disposal discussed the application of risk in safety assessments that consider uncertainty in long-term repository performance. The application of risk to both the potential for a scenario to occur and the effects of the scenario was considered. The report stressed the importance of considering Japan’s regulatory system promptly, taking into account the introduction of risk as a basis for establishing regulations in most other countries. Hence, the requirement to ensure safety and the corresponding safety assessment methodologies for intermediate-depth disposal of TRU waste will be evaluated in depth in the future. Bearing this in mind, the 2nd TRU progress report presents an evaluation for a groundwater scenario based on parameter ranges consistent with the nuclide partition coefficient (Kd) values for cementitious material used in the evaluation of the geological disposal system and the disposal concept and safety assessment presented in the 1st TRU progress report.

In the Advisory Committee Report, wastes for intermediate-depth and geological disposal are classified as those with an average alpha concentration provisionally specified to be in the order of several GBq/t (maximum concentration of several tens of GBq/t). The 2nd TRU progress report presents a re-evaluation of the alpha concentrations used for classification, to ensure that they are reasonable in terms of their implications for safety.

Additional analyses aimed at rationalization were carried out, taking into account the large reduction in waste volumes, storage requirements and required transportation that will be possible with modification of the methods for returning TRU waste from overseas.

The actual circumstances of geological disposal of TRU, including the institutional framework, the disposal site and the specific geological environment, have not yet been decided. Consequently, work was aimed at improving safety margins and flexibility in selecting a geological environment. This was done by improving existing waste technology and evaluating alternative technologies and addressing processes involving large uncertainties, including the effects of nitric acid and bentonite-alkaline solution reactions.

To ensure transparency and traceability in preparing the 2nd TRU progress report, consideration was given to making the reasoning behind scientific judgments and decisions more clear. Meetings to exchange information were held with domestic experts (June 2004 and April 2005) and review meetings were held with Nagra (December 2003, April 2004 and February 2005). At these meetings, the parameters and data used in the technical assessments and the assessment models were discussed. Many comments were received and are reflected in the final version of the report. Additionally, to facilitate exchange of opinions with experts from various countries and collection of information on current progress in research and development, the 3rd International TRU Workshop was held in Oxford, UK, in January 2005. The results of the meeting are also taken into account in this report.

The justification for selecting the data and parameter values used in the analyses in the report, together with supporting detailed analyses, have been published separately as a collection of supporting material (CD-ROM, http://www.fepc-atomic.jp/nuclear/waste/tru/002.html). These online documents (in Japanese) include a waste database, a nuclide migration database, design evaluation and analysis documentation, safety assessment scenarios, discrete phenomena analyses, safety assessments and details of the evaluation of co-site disposal.

1.2 Safety assurance for a geological repository

1.2.1 Background

In the safety assessment of a geological repository for radioactive waste, it is important to show that long-term safety can be assured after closure of the facility. In this section, safety assurance concepts for a geological repository for TRU waste are considered with reference to international trends and existing Japanese assessments.

The International Atomic Energy Agency (IAEA) has published a document entitled “Geological Disposal of Radioactive Waste: Draft safety requirements: Safety Standards Series DS154” (DS154; IAEA, 2004), which was produced with the aim of safeguarding geological repositories and as a basis for defining safety standards. It presents the basic requirements that must be fulfilled to ensure the safety of disposal in accordance with existing principles.

DS154 presents the requirements for ensuring long-term radiological safety, particularly after closure of the disposal facility. It is stated in Requirement 2 that it is the responsibility of the regulatory agency to “establish the regulatory requirements for the development of geological disposal facilities”. Requirement 3 states that “The operator of a geological disposal facility shall be responsible for its safety”. Additionally, it is the responsibility of the operator to “carry out safety assessments and develop a safety case, and carry out all the activities needed for siting, design, construction, operation and closure, in compliance with the regulatory requirements and within the national legal framework.”

In Japan, safety regulations corresponding to these requirements have been considered for a geological repository for high-level waste (NSC, 2000b), for a shallow disposal system for low-level waste from nuclear power plants (NSC, 1985, 1986, 1992, 2000a) and for a shallow disposal system for radioisotope (RI) waste (NSC, 2003). Also, common requirements for those wastes are documented in the “Common Important Issues for Safety Regulations of Radioactive Waste” (NSC, 2004). However, the principles for ensuring the safety of a geological repository for TRU waste have not yet been clearly defined. Although these principles will be considered in the future, it is important, before these deliberations, to obtain fundamental information and to perform related safety assessments. The results of these assessments will contribute to the development of necessary institutional framework and the planning of a geological repository for TRU waste.

In this report, Requirement 3 of DS154 is applied with appropriately, since the present report considers the framework for ensuring safety from the point of view of the waste producers. The evaluation of TRU waste disposal was carried out in accordance with this requirement. The safety requirements considered in this report are described in Section 1.2.2.

1.2.2 Safety requirements

As mentioned previously, the principles for ensuring the safety of a geological repository for TRU waste in Japan are not clearly defined at present. Therefore, the principles applying to the safety regulation of high-level waste disposal, examples from foreign countries and international agreements on disposal safety were evaluated. In the present report, the principles for ensuring the safety of the TRU repository are based on DS-154 which is consistent with the international principles on radioactive waste management (IAEA, 1995).

Not all the safety requirements of DS154 are considered to be important in the present technical evaluation of a TRU repository. In the present report, they are treated according to the following classification:

(i) Not a requirement for waste producers and hence not applicable
(ii) Not a requirement in the current technical evaluation and hence not applicable
(iii) Applied appropriately as a prerequisite to the technical evaluation
(iv) Applied appropriately as a common requirement of the technical evaluation
(v) A requirement for understanding the volume and characteristics of the generated waste
(vi) Applied appropriately as a disposal system design requirement
(vii) Applied appropriately as a safety assessment requirement

The evaluation in the present report focuses on requirements (iii) to (vii). Of these, (iv) to (vii) of the technical requirements are considered as safety requirements in this report. Table 1.2-1 shows safety factors that are considered to be important in this report and the corresponding requirement number of DS154.

1.2.3 Safety standards

Different countries adopt different types of safety standards for geological disposal of radioactive waste. Some apply dose limits and analogous dose criteria, while others use risk criteria (e.g. NRC, 1982/2002; DSIN, 1991; BMU, 2001; RSA93, 1997; SSI, 1998/2000; STUK, 2001/2003; HSK & KSA, 1993).

In Japan, regulatory guidelines have been specified to ensure radiation protection after the management period for low-level waste suitable for shallow disposal (NSC, 1988). According to these guidelines, the dose should not exceed 10 μSv/y due to generally occurring phenomena and should not significantly exceed 10 μSv/y due to phenomena with a low likelihood of occurrence. The same guidelines are adopted for regulating the safety of the component of TRU waste destined for shallow disposal. However, although the same basic safety principles are being considered for intermediate-depth disposal and deep geological disposal (AEC, 1998; NSC, 2000b), concrete safety standards have not yet been developed.

In Japan, as in other countries, different disposal methods are being considered depending on the different types and characteristics of radioactive waste. The "Common Important Issues for Safety Regulations of Radioactive Waste" (NSC, 2004) mentioned above points out that the detailed regulatory requirements should conform to the various methods of waste disposal and that separate approaches should be implemented for different wastes. However, it was also stated that the following basic considerations are relevant to safety regulation for every disposal method: (i) Introduction of a risk concept by taking into account the possibility that a particular scenario may occur; (ii) radiation protection standards taking into account the possibility that a particular scenario may occur; (iii) definition of the evaluation period, (iv) definition of the extent of treatment of human intrusion. It was also pointed out that the recommendations of the International Commission on Radiological Protection and regulatory trends in foreign countries should be taken into account.

In view of the above progress in Japan on definition of safety standards, the present report considers that, for TRU waste, an appropriate safety standard for a shallow disposal system is a dose rate of 10 μSv/y and that an appropriate standard for long-term safety after closure of facilities for intermediate-depth disposal and deep geological disposal, according to point (ii), is the same as that proposed in foreign countries (i.e. a dose rate 100 – 300 μSv/y or a risk of 10^{-5} – 10^{-6}/y).

Table 1.2-1 Safety requirements in this report

General item	Requirement	Requirement no. in DS154 (IAEA, 2004)
(i) Common requirements for technical evaluation	-Specific demonstration of disposal facility safety and level of reliability of safety	Requirement 12
	-Consideration of temporal and spatial variations	Requirement 12
	-Showing that there is no problem that might compromise safety	Requirement 12
	-Presentation of unsolved problems	Requirement 12
	-Ensuring adequate documentation (justification, tracking performance, clarity)	Requirement 13
	-Exchanging opinions with internal and external reviewers	Requirement 13
	-Quality management (including models used, data and verification and validation of codes)	Requirement 23
(ii) Requirements for understanding the volumes and characteristics of generated waste	-Understanding the inventory and characteristics of radionuclides and related factors (thermal output, matrix, package, etc.)	Requirement 19
(iii) Disposal system design requirements	-Design of passive engineered barrier system with multiple safety function	Requirement 7
	-Design of disposal system for containment, low flow rate, diffusion, dispersion, dilution and retardation	Requirement 7 Requirement 8
	-Design of appropriate infrastructure and layout	Requirement 9, Requirement 15
	-Design to reduce hazardous phenomena and perturbations	Requirement 15
	-Design taking into account the interactions between different barrier components, with the aim of maximizing their complementary effects	Requirement 7, Requirement 15
	-Design to minimize the effects of human intrusion	Requirement 9
	-Design to ensure safety during operation	Requirement 12 Requirement 15
(iv) Safety assessment requirements	-Ensuring that the results of the safety assessment are sufficiently reliable	Requirement 6
	-Understanding the characteristics and processes that contribute to safety; identification and understanding of phenomena and processes that might be detrimental to safety	Requirement 6
	-Considering of uncertainty in the safety assessment	Requirement 6
	-Checking adequacy of research scope (assessment timescale, assessed events/scenarios, analytical case)	Requirement 12
	- Application of multiple arguments based on the results of sensitivity analysis, analysis of the significance of uncertainty, "what if" analysis, reserve FEPs, stylized approach, adopting complementary safety indicators and natural analogue research	Requirement 9 Requirement 12

1.3 Geological environment

The geological environment at the site for the disposal facility plays an important role in ensuring the long-term safety of waste disposal. Important functions of the geological environment include physically isolating the waste from the surface environment, preventing migration of nuclides from the repository and maintaining the long-term stability of the facility. When selecting a repository site, it is necessary to consider whether the geological environment will fulfill these roles adequately. The disposal of TRU waste is presently at the evaluation stage that precedes the site selection stage and, consequently, the actual geological environment of the repository cannot yet be described in detail. The H12 report (JNC, 2000) showed that, in Japan, there are geological environments that would offer long-term stability of the rock formations and hence the safety of a HLW disposal facility. The present report therefore assumes geological environment conditions based on this knowledge.

1.3.1 Principles for selecting the geological environment

The most appropriate disposal concept for TRU waste depends on the radioactivity of the waste. The waste is classified into that which is suitable for shallow burial and that which is suitable for other disposal methods. Analysis results have been presented for the latter (AEC, 2000a; TRU Coordination Team, 2000).

In the ongoing deep geological and shallow disposal projects in Japan, different research and development approaches are adopted and the geological environment conditions and parameter values must be selected differently in each case. In this report, the geological environments for deep geological disposal and shallow disposal were selected according to the principles outlined in the following sections.

1.3.1.1 Geological disposal

The concept of geological disposal is based on a multiple barrier system consisting of engineered and natural components. The geological disposal concept has to consider a wide range of geological environment conditions in Japan. At present, a generic geological environment is assumed for the repository project. The evaluation of the geological conditions in the 1st TRU progress report (TRU Coordination Team, 2000) was performed by considering the investigation results for the geological environment presented in the H12 report. A range of conditions was taken into consideration by establishing several typical patterns for the geological environment.

1.3.1.2 Concrete vault disposal and intermediate-depth disposal

Some TRU waste can potentially be disposed of by shallow burial. A general safety assessment of this disposal option for power plant operational and decommissioning waste has already been performed (NSC, 1987; AEC, 1998; NSC, 2000a). Hence, in the work reported here, the geological conditions for this disposal concept were selected with reference to the evaluation of a generic geological environment by the Nuclear Safety Commission.

1.3.2 Range of geological environments and the reference case

1.3.2.1 Geological repository

This report sets the geological environment conditions based on the H12 report, which summarizes the large body of knowledge on the geological environment in Japan, and takes into account a range of non-site-specific geological conditions. The specification of the main parameters is described below and is summarized in Table 1.3-1.

Table 1.3-1 Specification of parameters for the geological environment for a repository

<table>
<tr><th></th><th colspan="3">A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>Geography</td><td colspan="3">Inland</td><td><u>Inland</u></td><td>Coast</td><td>Coast</td></tr>
<tr><td>Topographic features</td><td colspan="3">Plain
(hills, mountains)</td><td><u>Plain</u>
(hills, mountains)</td><td>Plain</td><td>Plain</td></tr>
<tr><td>Lithology</td><td colspan="3">Sedimentary rock</td><td><u>Crystalline rock</u></td><td>Sedimentary rock</td><td>Crystalline rock</td></tr>
<tr><td>Groundwater origin</td><td colspan="3">Precipitation</td><td><u>Precipitation</u></td><td>Oceanic</td><td>Oceanic</td></tr>
<tr><td>Transmissivity*1
(m^2/s)</td><td colspan="3">10^{-10}
(10^{-9}, 10^{-11})</td><td><u>10^{-10}</u>
(10^{-9}, 10^{-11})</td><td>10^{-10}
(10^{-9}, 10^{-11})</td><td>10^{-10}
(10^{-9}, 10^{-11})</td></tr>
<tr><td>Hydraulic conductivity
($m\ s^{-1}$)</td><td colspan="3">10^{-9}
(10^{-8}, 10^{-10})</td><td></td><td>10^{-9}
(10^{-8}, 10^{-10})</td><td></td></tr>
<tr><td>Hydraulic gradient</td><td colspan="3">0.01 (0.05)</td><td><u>0.01</u> (0.05)</td><td>0.01</td><td>0.01</td></tr>
<tr><td>Host rock type*2</td><td>SR-C</td><td>(SR-B)</td><td>(SR-D)</td><td><u>HR</u></td><td>SR-C</td><td>HR</td></tr>
<tr><td>Effective porosity (-)</td><td>0.3</td><td>0.2</td><td>0.45</td><td><u>0.02</u></td><td>0.3</td><td>0.02</td></tr>
<tr><td>Uniaxial compressive strength (MPa)</td><td>15</td><td>20</td><td>10</td><td><u>115</u></td><td>15</td><td>115</td></tr>
<tr><td>Disposal depth (m)</td><td colspan="3">500</td><td><u>1,000</u></td><td>500</td><td>500</td></tr>
<tr><td>Biosphere</td><td colspan="3">River water</td><td><u>River water</u></td><td>Seawater</td><td>Seawater</td></tr>
</table>

Note 1: Underlined entries indicate the reference conditions.

Note 2: In this report, ranges for permeability and strength, etc. of the host rocks are set separately for each evaluation, considering its purpose (e.g. whether aimed at tunnel stability analysis, nuclide migration analysis, etc.).

*1: The given values means the log average of the distribution.of transmissivity

*2: HR (hard rock) dataset: 0.02 effective porosity and 115 MPa uniaxial compressive strength; SR-B (soft rock B dataset): 0.2 effective porosity and 20 MPa uniaxial compressive strength; SR-C (soft rock C dataset): 0.3 effective porosity and 15 MPa uniaxial compressive strength; SR-D (soft rock D dataset): 0.45 effective porosity and 10 MPa uniaxial compressive strength.

(1) Topography

Combinations of the features below were used to represent the topography, based on the overall topography of the Japanese archipelago. With the aim of representing the relationship between geography and water quality, two typical groups of land forms were selected for evaluation from these combinations of features: one inland with a plain and freshwater type groundwater and one coastal with a plain and saline groundwater. However, for a plain with freshwater type groundwater, several variations of topography (mountains and hills) were considered.

- Geography: inland, coast
- Topography: mountains, hills, plain (plateau and lowland)
- Water type: freshwater, seawater

(2) Rock type

In the H12 report, rock types in Japan are classified into six categories as follows:

Crystalline “acidic rock” (igneous rock, metamorphic rock)
Crystalline “basic rock” (igneous rock, metamorphic rock)
Pre-Neogene sedimentary rock (sandstone)
Pre-Neogene sedimentary rock (mudstone/tuff)
Neogene sedimentary rock (sandstone)
Neogene sedimentary rock (mudstone/tuff)

In this report, crystalline acidic rock (granite) and Neogene sedimentary rock (mudstone/tuff) were selected as typical rocks, defined by their mechanical properties and taking into account their influence on nuclide migration and the mechanical stability of caverns. Each of these two lithologies was assumed to occur individually in combination with each of the two typical land form outlined above. Thus, in total, four typical cases were assumed.

(3) Geological structure

Nuclide migration from the repository through the natural barrier to the biosphere is considered to occur via long and complicated pathways because of the presence of geological structures, including faults. However, in the work reported here it was difficult to specify the nuclide migration pathways because a specific site has not been selected. The safety assessment in the H12 report considered the effect on the stability and performance of the repository of an active fault and an associated large-scale, high-permeability fracture zone located at a distance of 100 m.

Hence, in this report the reference case for the assessment assumes the thickness of the natural barrier is 100 m . Additionally, in order to evaluate natural barrier performance, crystalline rock is treated as a fractured medium. In contrast, in cases where the natural barrier is a sedimentary-type basement rock, it was generally approximated as a porous medium or as a combination of fractured and porous rock. In this report, radionuclide migration in sedimentary-type host rock was evaluated using overlapping 1D parallel surface models, as described in the H12 report for the evaluation of fractured media in crystalline rock.

(4) Hydraulic conditions

The hydraulic gradient was based on a synthesis of information on groundwater levels in the H12 report. Values for the hydraulic gradient were then selected to correspond to each type of topography, as given below:

Plain (plateau and lowland): 0.01
Mountains, hills: 0.05

The reference migration analysis for fractured media also used the transmissivity data from the H12 report. The reported values for transmissivity distribution (log average value -9.99, logarithmic standard deviation 1.07) were obtained from a permeability test performed in a borehole in the Kamaishi mine. However, in order to evaluate the variation range of environmental transmissivity distribution, two alternative cases were considered, one with a transmissivity distribution one order of magnitude smaller and a second with a distribution one order of magnitude higher. Based on the information from the H12 report, the parameter range for hydraulic conductivity of basement rock was assumed to be 10^{-8} m s^{-1} – 10^{-10} m s^{-1} for crystalline and sedimentary rock. The reference case was specified as having the hydraulic conductivity of 10^{-9} m s^{-1}.

(5) Groundwater chemistry

The characteristics of groundwater depend on the surrounding topography. In this report, freshwater type groundwater, which is the most common type in Japan according to statistical analyses using groundwater data from present references in the H12 report, is selected as reference groundwater type and seawater type groundwater will be considered as the variation of reference groundwater type.

(6) Rock mechanics

The strength of the host rock is an important factor which affects disposal facility design from the viewpoint of ensuring cavity stability. The existing data on physical properties of basement rock in Japan were presented in the H12 report and used to derive a dataset of basic physical properties of basement rock. In the present report, the data for a hard rock system (HR: average value of acidic rock) in the H12 report are used for crystalline rock. To represent the wide range of rock strength distribution shown by sedimentary rocks, three different cases were taken from the H12 report. The soft SR-C basement rock was taken as the reference case and the cases SR-B and SR-D were taken as alternatives.

1.3.2.2 Concrete vault disposal and intermediate-depth disposal

The possibility of disposing of a component of TRU waste in concrete vaults at a depth of several meters below ground surface or in intermediate-depth disposal facilities (e.g. 50 - 100 m) have been considered previously (AEC, 2000a, TRU Coordination Team, 2000). Hence, in this report, taking into account the evaluation of the Nuclear Safety Commission, the geological environment conditions for concrete vault disposal and intermediate-depth disposal are as shown in Table 1.3-2.

1.3.3 Summary

Referring to the ranges of geological conditions documented in the H12 report for deep geological disposal, four typical cases were specified. Additionally, for shallow disposal, the geological conditions in this report were established by considering the results of an assessment of shallow disposal of power plant waste performed by the Atomic Energy Commission of Japan and the Nuclear Safety Commission of Japan.

Table 1.3-2 Specification of geological environment conditions for shallow and intermediate-depth disposal

	Item	Subsidiary item	Set value	Remarks
Shallow disposal	Geological conditions	Nuclide migration pathway	500 m	The value near the center of the range 100–1,000 m, which is stated to be reasonable in IAEA-TECDOC-401.
	Hydraulic conditions	Hydraulic conductivity	10^{-6} m s^{-1}	0.01 m/d is set as the actual flow rate for groundwater.
		Porosity	0.3	
		Hydraulic gradient	0.01	
Intermediate-depth disposal	Geological conditions	Nuclide migration path length	500 m	Use as porous media On-site: 200 m Off-site: 300 m
	Hydraulic conditions	Hydraulic conductivity	10^{-7} m s^{-1}	The hydraulic conductivity shown to the left is applied to the in situ underground environment. The off-site value is 10^{-6} ms^{-1}, one order of magnitude higher.
		Porosity	0.2	The porosity is set by considering the value in “Groundwater Handbook” (Chikasui Handobukku Henshu-iinkai, 1979) and the H12 report.
		Hydraulic gradient	0.01	The gradient is set based on the hydraulic gradient distribution quoted for lowland in the H12 report.

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