ASSESSMENT OF PRE- AND POST-CLOSURE SAFETY IN THE NUMO SAFETY CASE FOR A GEOLOGICAL REPOSITORY


Nuclear Waste Management Organization of Japan (NUMO), Tokyo, Japan

E-mail contact of main author: ssuzuki@numo.or.jp

Abstract. The NUMO safety case is established to improve the confidence of pre- and post-closure safety in the Japanese geological disposal programme at the current stage prior to selection of a site. The pre-closure safety case aims to assure both radiological and non-radiological protection of the public and workers. Radiological protection requires radiation shielding and radionuclide containment within the disposal facilities in case of operational perturbations. Operational perturbations, such as physical or thermal impacts on the waste-form, are analysed using an event tree method and possible, cost-effective counter-measures identified that would reduce their likelihood or mitigate their impact. Potential vulnerabilities of operational processes have been considered: most of these would pose little risk to the public, but the complexity of recovery operations and risks to workers could be significant. For protection from non-radiological hazards, the working environment will be maintained to ensure worker comfort and safety during normal operations. In many cases, requirements are set out in regulatory guidelines – e.g. for the ventilation system. Further, underground tunnels and ventilation shafts should be laid out to facilitate ventilation pathways, taking transport routes for excavated rock and waste and required active / inactive zoning into consideration.

Long-term, post-closure performance assessment is required to evaluate safety functions of specific repository systems, with consideration of uncertainties in a realistic and rational manner, excluding excess conservativeness. This is particularly required during site investigation to allow the pros and cons of potential sites to be identified and the appropriateness of particular repository concepts for such sites to be evaluated. Based on these requirements, an appropriate methodology has been developed for long-term performance assessment in this safety case. The methodology of scenario development, which results from a desire to combine a more conventional, bottom-up, FEP-based approach and a top-down method based on safety functions, is appropriate to this risk-informed assessment approach. This methodology, including overall procedures and associated toolkits, aims to increase traceability and transparency. Additionally, by clearly reflecting the purpose and context of the safety case and state-of-the-art knowledge, it assures appropriate degrees of completeness, comprehensiveness and sufficiency within the scenario development process. The methodology of safety analysis, which reflects the characteristics of site and repository design as faithfully as possible, has been improved. In particular, a radionuclide migration model for “near-field scale” (= several hundred meters) has been developed based on three-dimensional mass transport analysis that reflects key characteristics of the site and the associated repository design.

Key Words: Geological disposal, vitrified waste, TRU wastes, safety case

1. Introduction

NUMO has developed a safety case for co-disposal of HLW and TRU waste to reflect current boundary conditions in Japan, in particular siting based on an initial open call for communities to volunteer for initial site assessment. In particular, this involves addressing public concerns and actions by the Government to more strongly support moving forward with siting a geological repository, involving suggesting locations that are considered to be more scientifically suitable.

The current Safety Case advances from the previous “H12 Report” [1], which formed the basis for establishing NUMO in 2000 as the implementing organisation and is considered the first generic safety case in Japan. The NUMO Safety Case has been developed to provide a
basic structure for subsequent safety cases that could be applied to any selected site, emphasising the practical approaches and methodology, which will be applicable for the conditions/constraints during an actual siting process. The NUMO Safety Case has been extended in key areas, including assessing extreme geological events during long-term repository evolution, widening discussion of both operational and post-closure safety, scenario development based on a risk-informed approach, etc. This paper describes the central issues of the safety case concerned with assessment of pre- and post-closure safety.

2. Assessment of pre-closure safety
The reference inventory includes vitrified waste produced as a result of the reprocessing of spent fuel and “TRU waste”, which contains various types of intermediate level (but long lived) radioactive wastes produced by reprocessing and MOX fabrication. According to the final disposal plan [2], 40,000 packages of vitrified waste and a volume of 19,000 m$^3$ of TRU waste will be need to be disposed of. Radioactive protection of public and workers and non-radiological, conventional safety for workers during construction, operation and closure of repository are discussed.

2.1. Facility design for the radiological protection of the public and workers
Radiological protection requires radiation shielding and radionuclide containment within the disposal facilities for all operations, extended to additionally cover potential operational perturbations. Radiation control and facility design are based on guidelines for other nuclear facilities [3]. Within radiation-controlled zones, most operations will be remote-handled or will involve appropriate shielding, avoiding any significant dose to workers. Under normal operations, radiological exposure of the public results only from highly penetrating radiation at or beyond the site boundary. Even assuming maximum exposure times, the expected dose beyond the boundary from the HLW handling facilities would be far below the upper limit of radiation exposure to the general public.

To design safety measures, hazard scenarios were developed to identify operational perturbations resulting in physical or thermal impacts on the waste-form. The scenarios were made using event tree methodology and from this, possible, cost-effective counter-measures identified that would reduce their likelihood or mitigate their impact, on the basis of defense-in-depth. TABLE 1 shows the multiple measures for the fire incident.

<table>
<thead>
<tr>
<th>TABLE 1: MITIGATION MEASURES FOR IDENTIFIED HAZARDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level in event sequence diagram</strong></td>
</tr>
</tbody>
</table>
| Prevention of incident initiating fire | ➢ Prevention of incidents providing ignition  
➢ Elimination of combustible materials |
| Prevention of fire propagation | ➢ Elimination of combustible materials  
➢ Detection of fire (e.g. Thermal/smoke detector)  
➢ Fire extinguishing equipment |
| Mitigation of radionuclide release accidents due to fire incident | ➢ Emergency exhaust filter system (if radionuclide release is detected) |
| Safety of workers (linked to conventional safety issues) | ➢ Evacuation routes  
➢ Emergency shelters |

Measures such as those mentioned above are designed to provide sufficient safety margins; however, the assessment conservatively assumes if all safety measures could fail. In practice, the mechanical robustness of metal packages effectively assures no release of radionuclides as a result of credible incidents in the underground facility. Potential vulnerabilities of operational processes have been considered: most of these would pose little risk to the public, but the complexity of recovery operations and risks to workers could be significant.
2.2. Facility design for the conventional safety of workers

For non-radiological protection, the working environment will be maintained to ensure worker comfort and safety during normal operations. In many cases, requirements are set out in regulatory guidelines – e.g. for the ventilation system. Further, underground tunnels and ventilation shafts should be laid out to facilitate ventilation pathways, taking transport routes for excavated rock and waste and required active / inactive zoning into consideration. For accident situations, such as a fire underground, the evacuation pathways would be routed along the air intake shaft, with emergency shelters provided at appropriate locations.

To fulfill such requirements, we developed a simpler concept: involving a twin emplacement panel layout concept based on dead-end tunnels. In this concept, two horizontal connecting tunnels are utilized (FIGURE 1), with each tunnel operated independently for construction or operation. After finishing the construction of a disposal panel, the connecting tunnel and the constructed area are used for waste emplacement, while new panel excavation starts from the other connecting tunnel. Thus, the operation, ventilation and water drainage system will switch from normal area to a radiation-controlled area in a cyclic manner. This concept may also provide a simple evacuation pathway for emergencies such as fires.

FIG. 1 Schematic view of the twin emplacement panel layout concept.

3. Assessment of post-closure safety

3.1. Framework for post-closure safety assessment

Adopting a risk-informed assessment approach, assessment scenarios related to natural events and processes are classified into three categories related to the probability of their occurrence – i.e. “likely”, “less-likely” and “very unlikely”. Scenarios related to human intrusion are treated based on a stylized approach, in line with the principle that such human intrusion scenarios are evaluated primarily to assess the robustness of the disposal system [4].

3.2. Scenario development

NUMO developed a hybrid scenario development methodology combining top-down (safety functions) and bottom-up (FEP-based) approaches in a complementary manner [5]. Specifically, the variables which influence a safety function allocated to a component of the system are defined, and the factors which influence these variables are selected from the FEP database (FIGURE 2). The treatment of each factor in a specific scenarios is determined by assessing the probability and significance of its occurrence.
3.3 Modelling of radionuclide migration

The safety analysis methodology has been improved to reflect the characteristics of site and repository design as faithfully as possible. In particular, a radionuclide migration model for the “near-field scale” (≈ several hundred metres) has been developed based on a three-dimensional mass transport analysis that represents key characteristics of the site and the associated repository design. 3-D solute transport pathways are evaluated by a particle tracking method. The various calculation cases for the safety assessment scenarios should be carried out flexibly and efficiently, so radionuclide migration analysis taking account of retardation processes is conducted by using 1-D model. To better represent the case examined, the 1-D radionuclide model is fit to the solute transport properties obtained through 3-D particle tracking to create a 1-D multi-channel model.

4. Summary

The pre- and post-closure safety cases were demonstrated. The R&D will be continued to improve the confidence in Japan throughout the siting and development of repository.

REFERENCES


