nwmo

NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

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NWMO BACKGROUND PAPERS
3. HEALTH AND SAFETY

3-5 A RISK-BASED MONITORING FRAMEWORK FOR USED FUEL MANAGEMENT

EXECUTIVE SUMMARY

Nava C. Garisto, SENES Consultants Limited

EXECUTIVE SUMMARY

The Nuclear Waste Management Organization (NWMO) has a mandate from the Government of Canada to consult with the public and to recommend an approach for managing Canada's used nuclear fuel. Three main technical methods for managing used fuel are being explored and evaluated by the NWMO:

- disposal in a Deep Geological Repository (DGR);
- reactor-site extended storage (RES); and
- centralized extended storage (CES), either above ground or below ground.

The used nuclear fuel management system, whether a DGR or an extended storage system will require monitoring. The purpose of this study is to develop a risk-based monitoring framework for the used fuel management program. This is being carried out using a step-by-step approach with the following two major steps:

- First, the various management methods are reviewed to estimate potential risks at each stage of their development.
- Second, the results of the review are used to develop, at a conceptual level, a monitoring framework, which focuses on the main areas of potential risk.

STEP 1 - Potential Risks

This review step provides a high-level perspective, based on available information, on what is known regarding potential risk to the public, workers and the environment for the three management methods considered (see Tables ES-1 to ES-3). The risk assessment presented is based on a combination of operating experience at the nuclear sites in Ontario (Pickering, Darlington, Bruce) as well as Canadian and international assessments. The possible effects are not limited to only present-day conditions as risks may also arise in the far future*. Detailed discussions of the risk associated with the various stages of implementation of each option, are given in Appendices attached to the Main Report.

Both routine operating conditions and hypothetical accident scenarios are evaluated considering both radiological and non-radiological (conventional) effects.

* However, since about 98% of the used fuel is natural uranium, as radionuclides decay, the radioactivity in the system will in the long term become similar to that of natural uranium ore bodies found in Canada.

TABLE ES-1 – OVERVIEW OF STAGES IN THE DEVELOPMENT OF DEEP GEOLOGICAL DISPOSAL AND POTENTIAL RISKS

Stage	Non-radiological Effects		Radiological Effects	
	On site worker	Off site resident	On site worker	Off site resident
Siting				
Construction				
Operation				
Transportation				
Extended Monitoring, Decommissioning and Closure				
Post Closure				
Inadvertent Human Intrusion				

TABLE ES-2– OVERVIEW OF STAGES IN THE DEVELOPMENT OF STORAGE AT REACTOR SITES AND POTENTIAL RISKS

Stage	Non-radiological Effects		Radiological Effects	
	On site worker	Off site resident	On site worker	Off site resident
Site Preparation and Construction				
Operation				
Transportation				
Extended Monitoring				
Facility Repeat				
Repackaging				
Replacement of Modules and Baskets				
Extended Long Term Monitoring				

TABLE ES-3– OVERVIEW OF STAGES IN THE DEVELOPMENT OF CENTRALIZED STORAGE AND POTENTIAL RISKS

Stage	Non-radiological Effects		Radiological Effects	
	On site worker	Off site resident	On site worker	Off site resident
Site Preparation and Construction				
Operation				
Transportation				
Extended Monitoring				
Facility Repeat				
Repackaging				
Replacement of Modules and Baskets				
Extended Long Term Monitoring				

LEGEND

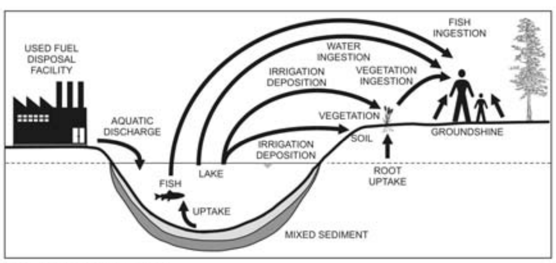
Green	No significant effect; very small risk of injury
Blue	Not assessed in detail
Purple	Potential exposure in the hypothetical and unlikely event of institutional collapse in the near-term and society memory loss of the site. No potential impact from DGR is expected if such a societal collapse occurs in the long term even in the case of human intrusion (because of gradual radioactive decay, see Appendix A).
Yellow	Theoretical potential lost time accident
Orange	Theoretical potential fatality

Brief examples of this evaluation are provided in Tables ES-1 to ES-3. Where emissions are thought to occur, the resulting exposure doses are compared to existing limits, guidelines and background values for perspective. Where there are gaps in current knowledge, these are noted, so that they can be addressed in a future analysis during the implementation of the monitoring program.

Radiological dose rates were estimated for the various stages in the implementation of each of the three types of facilities and for the public, workers and non-human biota (e.g., mammals, birds, fish) in each case.

The dose estimates were made using a comprehensive pathways analysis (see Figure ES-1a, b for pathways being considered). Example results for a deep geological repository and reactor-site extended storage are shown in Figures ES-2 and ES-3, respectively. Other routine and non-routine scenarios are provided in the Main Report and Appendices.

FIGURE ES-1a – KEY EXPOSURE PATHWAYS FOR SURFACE FACILITIES



SOURCE: Adapted from Russell, 1996

FIGURE ES-1a – KEY EXPOSURE PATHWAYS FOR UNDERGROUND FACILITIES

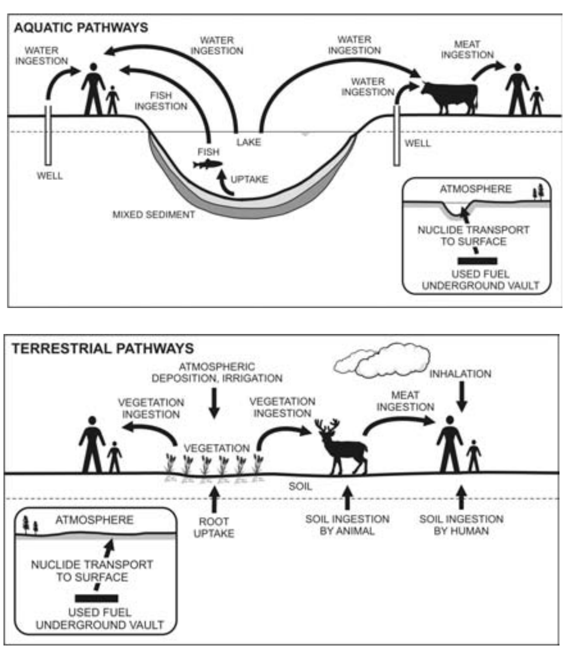
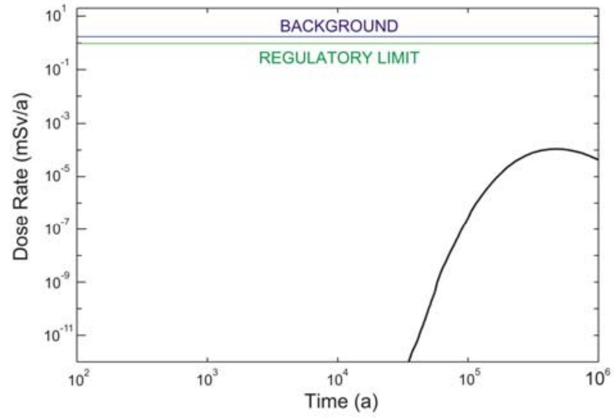
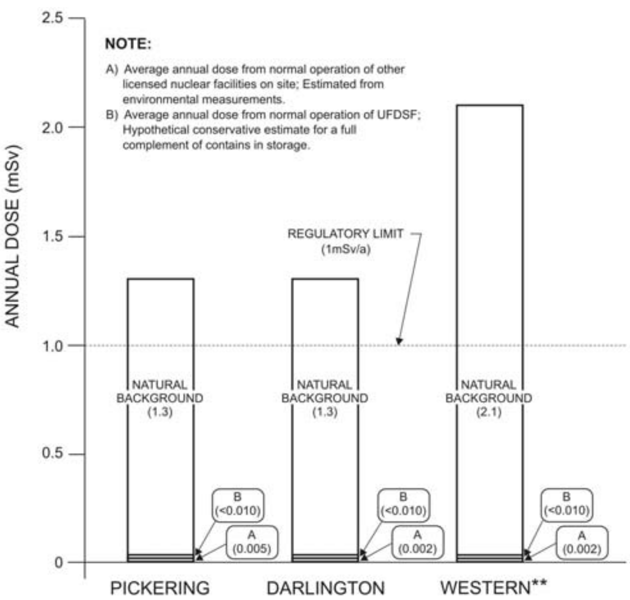


FIGURE ES-2 – DOSE RATE AS A FUNCTION OF TIME FOR THE POST-CLOSURE STAGE OF A DEEP GEOLOGICAL REPOSITORY



SOURCE: Adapted from Garisto et al, 2004

FIGURE ES-3 – ANNUAL PUBLIC DOSE FOR REACTOR-SITE EXTENDED STORAGE: OPERATING CONDITIONS*



* The operating experience from existing facilities has confirmed that the current dose rate to the public at the property boundary is less than 1% of the regulatory limit.

** Western refers to the Western Management Facility at the Bruce Site

The main conclusions from the Step 1 analysis are:

- Under current routine conditions, and based on available information, no significant impacts on human health or the environment, from any of the proposed technical management methods are expected.

- Conventional industrial and/or transportation accidents may occur in the implementation of these methods, as with any large industrial project. Such risks can be mitigated by the implementation of safety programs including worker education, strict implementation of safety procedures, and monitoring of this implementation. Some small differences between the options can be expected regarding risk from conventional accidents. For example, transportation risk is smaller for storage at reactor site than at a centralized facility.

- Overall, except for negligible changes in radiological dose after container failure, the total risk from a Deep Geological Repository decreases with time due to radioactive decay and the inherent passive nature of this disposal method.

- Over the long term, there may be a requirement to relocate the used fuel for the reactor-site extended storage and perhaps centralized extended storage (e.g., for above-ground facilities). This may be due to potential rise in surface water levels caused by climate-change factors such as global warming. Monitoring of climate conditions may be used to warn of the need for used-fuel facility relocation. Also, the impact of a far-future glaciation scenario has not been addressed in existing documentation on reactor-site extended storage and centralized extended storage. The consideration of such a scenario, may result in such facilities having to be relocated, prior to glaciation, to avoid glaciation related impacts.

  The risks associated with the extension of storage time at either reactor sites or a centralized location to very long times has not been studied quantitatively in detail. Such an assessment requires for example, an understanding of risks associated with potential loss of integrity of the fuel bundles (i.e., the cladding and potentially the fuel). However, a specific monitoring program can be developed to focus on this aspect of the performance of storage systems, to determine potential risk and decide on mitigation measures.

- Although radioactivity is often perceived as being a high risk factor associated with used fuel management, the estimated exposure doses for the various options are generally low in comparison to established national and international benchmarks.

- Current information on risks associated with the various options supports the safety of these systems under current conditions. Security risks such as acts of terrorism have not been evaluated in the present study.

- Several gaps in the risk estimates and its documentation were noted. However, none of these are considered to affect the overall conclusions from this study. They include a need:

  1. to update the documentation of risk assessments to ensure that they consider the current reference design concepts and alternatives studied by the NWMO;

  2. to complete the documentation of risk assessment from chemical emissions;

  3. to directly address potential specific human receptors (e.g., a specific documentation of potential risk to Aboriginals would enhance the transparency of the assessment, although most diets assumed in the current assessment encompass those of Aboriginal receptors);

  4. to complete and update the assessment of ecological risk to non-human biota (e.g., mammals, birds, fish).

  5. to re-evaluate the risk from transportation and if necessary, to develop mitigation measures to improve transportation safety.

These gaps will need to be addressed as part of the implementation of the approach selected by the federal Government for long-term management of nuclear fuel waste.

STEP 2 - Risk-Based Monitoring Framework

Monitoring is a set of activities that sample, measure and analyze radiological and chemical substances and physical parameters (e.g., temperature). The objective of monitoring activities is to demonstrate that adequate measures have been taken to protect the environment and to keep radiation doses to members of the public as low as reasonably achievable, social and economic factors taken into account.

A monitoring framework that addresses risks associated with used nuclear fuel management has been developed for the various technical methods relying on the results of risk assessments from Step 1. The proposed approach addresses the unique challenges of used fuel management being implemented in a multi-stakeholder process, including:

(i) The complexity of the facilities, i.e., the need to monitor multiple contaminants and pathways. - *This is addressed by using the results of the pathways analysis and risk assessments to define the main contaminants and environmental compartments that should be considered in the monitoring plans.*

(ii) The need to consider both science-based risk and perceived risk in the monitoring plans - *This is addressed by following a multi-stakeholder process that allows stakeholder input into the planning of risk-based monitoring (see Figure ES-4 and ES-5).*

(iii) The difficulty in conducting "invasive" measurements of sealed systems, particularly over a very long time frame - *This is addressed by developing a program of component-testing and by using monitoring boreholes that are sealed when not in use and periodically unsealed for measurement (see Figure ES-6).*

The above approach implies for example, for Deep Geological Disposal, even if the sealed repository is "out of sight" (because it is located deep underground) it can stay "monitorable".

The development of monitoring plans is an iterative process throughout the life cycle of the project (see Figure ES-5). As gaps in the risk assessment are gradually filled, the monitoring plans can be refined.

FIGURE ES-4 – THE MONITORING PLANNING PROCESS

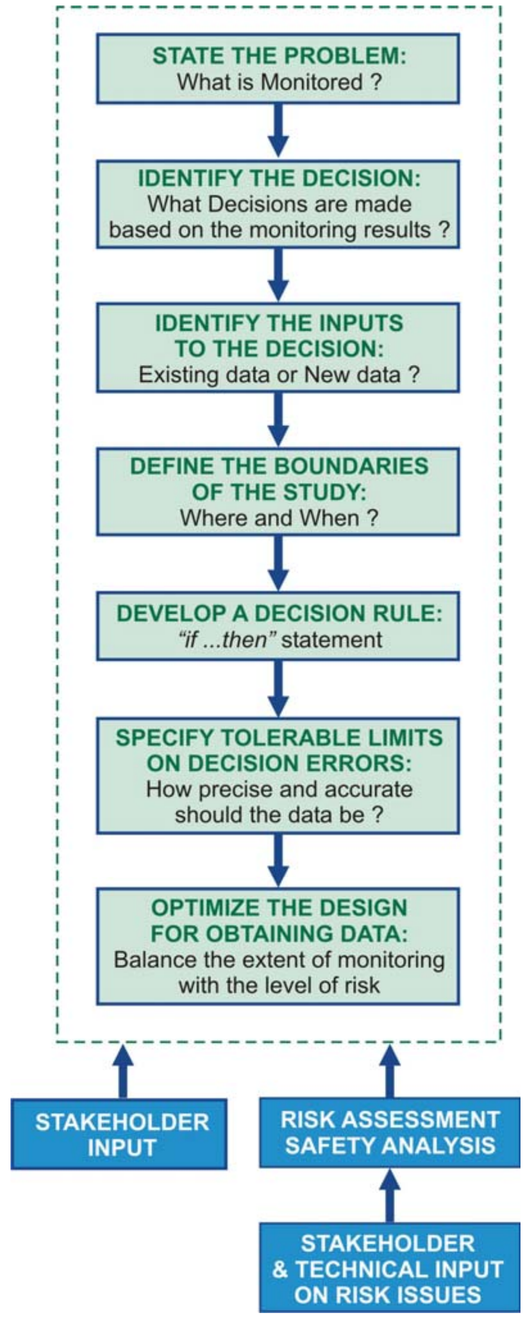
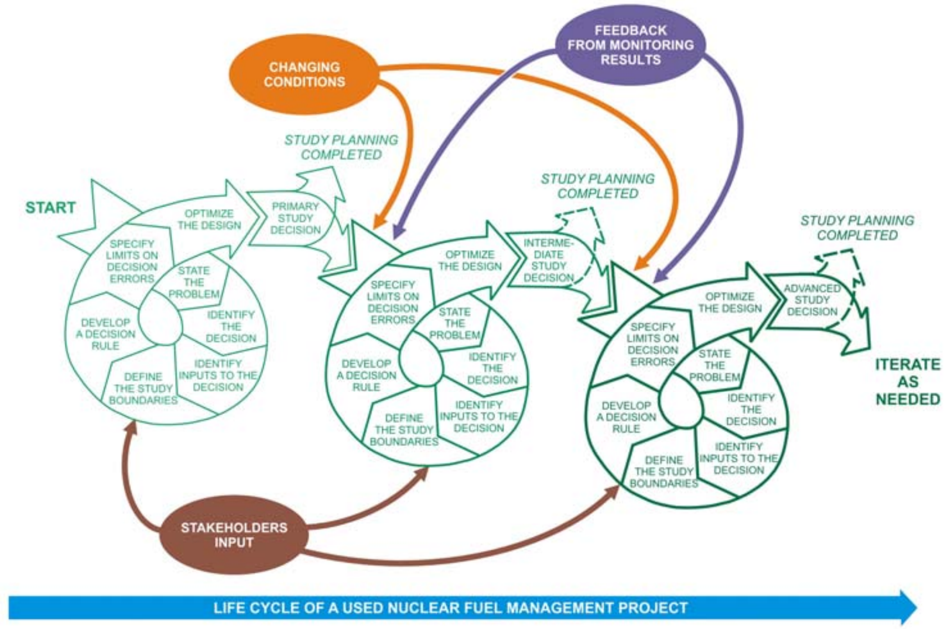


FIGURE ES-5 – REPEATED APPLICATION OF THE MONITORING PLANNING PROCESS THROUGHOUT THE LIFE CYCLE OF A PROJECT



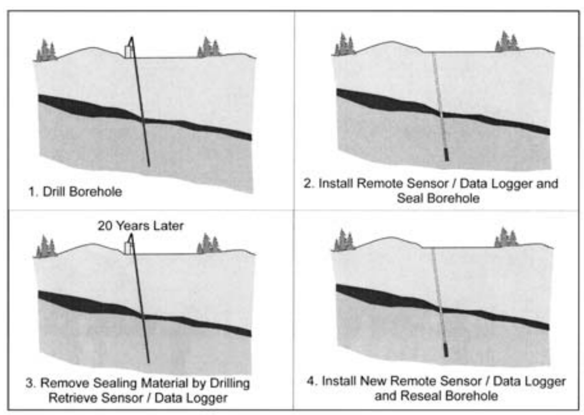
SOURCE: Adapted from U.S. EPA, 2000

Conclusion

Conceptual designs developed for the used-fuel management methods considered by the NWMO would all meet Canadian regulatory safety and environmental requirements. Regulatory compliance, however, does not imply that these concepts can be implemented under zero-risk conditions. Like any major industrial project, a nuclear used-fuel facility may result in a small risk to human health or the environment. This is the case even though all relevant regulations are met and particular care is taken to reduce the risk to as low as practically possible.

Potential risks may occur at different times and through different pathways for the different used-fuel management methods being considered by the NWMO. This report shows how an understanding of these risks can be used to develop a monitoring framework that focuses on the main risk pathways that are expected to affect the performance of the used-fuel management systems. Such a monitoring framework is based on the principle of "more risk => more monitoring" and is expected to complement routine monitoring done to demonstrate regulatory compliance.

FIGURE ES-6 – APPLICATION OF REMOTE DATA LOGGER/SENSOR ASSEMBLY TO LONG-TERM REPOSITORY MONITORING



Source: Extracted from Thompson and Simmons, 2003.

The monitoring framework discussed in this report is systematic, risk driven and iterative. It is based on a multi-stakeholder input process. It is expected that monitoring results will be used not only to determine compliance, but also to determine whether any aspects of the used-fuel management system (including monitoring) need to be modified to improve performance.

The iterative monitoring framework (Figure ES-5) enables the process to adapt to changes in stakeholder needs and in actual facility performance throughout the long life cycle of the project.