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Radioactive Materials Management

# Deep Geologic Repository Conceptual Design

## Annex 6

## Environmental Monitoring

December 2002

## NOTICE to the Reader

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## Summary

This report addresses the requirements and the implementation of a monitoring programme designed to evaluate the environmental effects of the deep geological repository (DGR) facility.

The report describes the requirements and general framework for environmental monitoring of the DGR and includes the development of an environmental monitoring plan and the relevant sampling and analytical requirements.

# Contents

# 1 Introduction

Possible approaches for the long-term management of used nuclear fuel are being reviewed in Canada. One of the options being considered is direct emplacement of the used fuel in a deep geologic repository (DGR) in a crystalline rock formation in the Canadian shield.

This option is based on a design concept that will ensure long-term isolation of the used fuel through a combination of engineered and natural barriers. The repository would be designed for passive safety so that no institutional controls would be necessary to ensure the safe, permanent isolation of the used fuel.

This report considers the requirements for environmental monitoring for the DGR facility from the start of the project and through its preclosure phase. This phase is defined to include all activities from siting through to decommissioning and closure of all components of the system. Preclosure monitoring is expected prior to and during the used fuel emplacement stage (approximately 30 years) and for up to 70 years following the completion of used fuel emplacement.

One of the requirements for the repository is that it must include comprehensive pre-operational environmental monitoring to gather information necessary to establish baseline conditions in the local environment.

The aims of this report are to describe and propose monitoring plans and systems that will demonstrate that the repository is not adversely effecting the environment and that its safety and performance targets are being met.

The report is structured as follows:

| | |
|---|---|
| Section 2 | Monitoring Objectives |
| Section 3 | Environmental Monitoring Concepts |
| Section 4 | Environmental Monitoring Plan |
| Section 5 | Conclusions |

# 2 Monitoring Objectives

Regular monitoring programmes, in respect to radioactive used fuel emplacement operations, are usually established to satisfy one or more of the following objectives:

(a) to estimate public radiation exposures, using appropriate additional data and models

(b) to comply with regulatory requirements

(c) to ensure that regulatory requirements have been met

(d) (for monitoring by regulators or local authorities) to check operators results

(e) to provide an independent means of surveillance for inadvertent or

unrecorded discharges

(f) to provide public reassurance

(g) (pre-operationally) to establish background levels

(h) to detect any long-term trends.

Usually, several of these objectives apply in the case of any given monitoring programme.

In addition, monitoring programmes may also be designed to provide information that can be used to quantify radiation exposure pathways and hence confirm the scientific basis of assessments of public radiation exposures.

The fundamental objective of repository environmental monitoring is to evaluate, quantitatively, the effect on the environment from the activities at the repository site. Such monitoring should ensure that the repository is compliant with regulatory targets.

During the preclosure period, parameters will be monitored both in and around the DGR to determine the effects of the facility on the environment. This will include the geosphere, atmosphere and the biological environment. Implications on humans and the social and economic effects of the project will also be considered.

It is expected that initially, during the siting phase, a parameter baseline will be established and, subsequently, the relevant environmental parameters will be monitored for a period of more than 100 years.

The specific criteria and requirements for monitoring will be developed as the detailed repository design becomes established, when the site-specific conditions are known and when the requirements for environmental performance for the repository have been established.

The types of systems and instrumentation that might be used will depend on key issues such as the timescales over which the monitoring will be required and the frequencies with which they will be undertaken. Similarly, the sensitivities required of the instrumentation will depend on the criteria to be established by the operator and the regulators of the repository.

The DGR operator will be required to demonstrate, prior to the construction of the repository, that there would be no significant adverse effects on the environment resulting from these activities that cannot be justified or mitigated by reasonable means. Whilst there would inevitably be much focus on the radiological aspects, the more conventional environmental concerns should also be addressed.

The environmental monitoring programme will be developed as part of the licensing process for the facility and in accordance with regulatory requirements.

The primary objectives of environmental monitoring in this context are therefore to:

- establish a baseline for the repository environment prior to construction
- quantify the effect of repository operations on the environment
- verify that radiation/hazardous material exposures to members of the public are compliant with operating targets and regulations
- demonstrate compliance with performance objectives and regulatory limits.

# 3 Environmental Monitoring Concepts

A comprehensive programme for environmental and radiation safety monitoring would be required as part of the licensing process for the facility and in accordance with regulatory requirements. As it is not clear at present what these requirements might be in detail, this section of the report has considered a generic approach that is likely to be broadly relevant.

A monitoring system would be established throughout all phases of the repository lifecycle. A comprehensive recording and reporting system that can be audited would be established. Independent verification programmes would also be established.

The monitoring system would provide a continuous review of radiation exposures and would demonstrate that all exposures are as low as reasonably achievable (ALARA) and that all dose limits and constraints are met. The monitoring results would be reviewed by both the operator of the facility and the regulators, on a regular basis, to determine whether safety and environmental objectives are being met.

The various requirements for environmental monitoring are described below:

**1. Environmental monitoring baseline**

During the operational and preclosure and postclosure surveillance phases of the repository, environmental monitoring would be conducted to determine whether any releases of radionuclides from the site are occurring and, if so, whether these are within the agreed limits. In order to judge this, the ambient background radiation levels of the site and its environs, need to be established. The baseline monitoring would address both the surface and subsurface environments. The programme would include the following environmental media:

- air
- surface water and groundwater
- soil
- flora
- fauna

The baseline monitoring would also identify the local ecosystems, and potential pathways for radionuclide transport through the environment and uptake by people.

Current surface water drainage patterns and habits of local flora/fauna and humans would be identified to aid the optimisation of the repository design, particularly with respect to the surface infrastructure arrangements.

**2. Quantify the impact of repository operations on the environment**

Operating procedures at the repository would be established to ensure that no unauthorised releases of radioactive material to the environment will occur. A monitoring programme would be established to confirm this. This programme would include routine measurements of:

- surface contamination (via instrument surveys and surface swabs)
- airborne contamination (via area monitoring with high-volume air samplers and personal air samplers)
- external radiation dose rates (via fixed monitoring/sampling stations and instrument surveys).

**3. Demonstrate that radiation/hazardous material exposures to members of the public are compliant with objectives and that exposures are within regulatory limits**

A dose assessment programme would be established for members of the public, which could include calculations of dose from dosimetric models and environmental data, the use of personal dosimeters or periodic (e.g. annual) urine sampling and analysis of a test group of individuals..

A dose assessment record would be generated for members of the public that can be reviewed by the operators, as well as the regulators..

**4. Demonstrate compliance with performance objectives and regulatory limits.**

The repository environment would be monitored during both the operational and the institutional control (post-closure) phases to ensure that any environmental effect is acceptable and meets all relevant requirements.

The monitoring system would include both sampling of the various media, as described in the baseline survey (i.e. air, surface water and groundwater, biota and soil) and their analysis for key contaminants.

# 4 Preparation of an Environmental Monitoring Plan

An environmental monitoring plan will be required for operations at the repository, covering both general environmental issues and the specific requirements of legislation and Codes of Practice in relation to radiation and radioactive used fuel repositories.

Development of the plan will take into account issues and responses raised in the environmental assessment process, as well as formal regulatory requirements.

The general aims of the monitoring plan will be to:

- Establish management processes and procedures that will ensure that environmental effects are minimized during construction, operation, surveillance and decommissioning
- Establish ongoing monitoring and reporting processes to follow the effects of the operation on the surrounding environment
- Establish audit processes for checking the implementation and effectiveness of management and monitoring systems.

## 4.1 MANAGEMENT AND MONITORING APPROACHES

A number of management and monitoring approaches will be required during the four key phases of the project i.e. construction, operation, the surveillance period and decommissioning.

### 4.1.1 Monitoring during Construction

This section describes the potential mechanisms for environmental effect during construction.

**Table 1 Environmental issues during Construction**

| Area | Issue |
|---|---|
| **Physical Environment** | |
| | Surface water run-off, soil erosion and siltation of water courses |
| | Dust Generation |
| | Noise |
| | Release of pollutants to soil, surface water or groundwater |
| **Vegetation and Flora** | |
| | Potential for introduction and dispersal of weeds |
| | Damage/removal of native vegetation |
| | Accelerated soil erosion |
| | Threatened species |
| **Fauna** | |
| | Direct loss of individuals |
| | Loss of habitat |
| | Increased competition for resources and predation |
| | Threatened species |
| | Pest species |
| | Fencing |
| **Socio-Economic** | |
| | Construction vehicle traffic |
| | Unauthorised site access and attempted access |
| | Land use conflicts |
| **Cultural Heritage** | |
| | Consultation with claimant groups |
| | Access to the repository sites |
| | Infrastructure and access within the repository site |
| **Radiation** | |
| | Establish the preconstruction conditions. |

The following table describes the monitoring requirements, where needed, for each of these areas.

**Table 2 Environmental Monitoring Requirements during Construction**

| Issue | Monitoring Requirement |
|---|---|
| **Physical Environment** | |
| Surface water runoff, soil erosion and siltation of watercourses | • Regular inspection of drainage lines for evidence of sediment transport<br>• Inspect bunded areas regularly to confirm integrity of bunds<br>• Inspect and maintain erosion control measures<br>• Clean up areas of accidental spillage of fuels and dispose appropriately |
| Dust | • Visual monitoring to determine areas of excessive dust generation and activities creating dust to ensure that any dust arising is minimal |
| Noise | • Measurement of noise levels during construction to ensure consistency with Industrial Noise Policy and OH&S requirements |
| Potential for release of pollutants to soil and surface water | • Ad hoc inspections following severe weather events<br>• Ad hoc inspections following any fuel/oil spills and after cleanup activities<br>• Opportunistic sampling of flowing surface water upstream and downstream of the site with analysis of salinity, turbidity/total suspended solids and selected radionuclides to build up background data set |
| Potential for release of pollutants to groundwater | • Continued analysis of existing monitoring wells to record any potential changes prior to emplacement of the used fuel |
| **Vegetation and Flora** | |
| Potential for introduction and dispersal of weeds | • Undertake preconstruction and postconstruction surveys of disturbed areas to identify the presence of any weeds, and remove and destroy any weeds found |
| Damage/removal of native vegetation | • Establish photopoint monitoring sites and baseline plans of existing conditions prior to construction<br>• Undertake quantitative surveys to establish biodiversity indicators (including non-vascular plants) for future monitoring |

| Issue | Monitoring Requirement |
|---|---|
| Threatened species | • Maintain a watching brief for presence of rare species within the site<br>• Monitor delineated populations (or individuals) for disturbance<br>• Monitor implemented conservation measures for level of success |
| Accelerated soil erosion | • Undertake preconstruction and postconstruction surveys to identify areas of potential erosion<br>• Monitor the effectiveness of water management techniques |
| **Fauna** | |
| Direct loss of individuals | • Monitor the presence of fauna in and around construction activities<br>• Conduct daily checks for trapped animals. Trapped animals are to be captured and released nearby |
| Loss of habitat | • Monitor as per Vegetation and Flora, above |
| Threatened species | • Monitor areas defined as no-go areas for effects on threatened species |
| Pest species | • Monitor the site for vertebrate and invertebrate pests |
| **Socio-Economic** | |
| Unauthorised site access and attempted access | • Maintain a record of unauthorised or attempted unauthorised intrusion |
| **Radiation** | |

| Issue | Monitoring Requirement |
|---|---|
| Preconstruction conditions | • The baseline monitoring would address both the surface and sub-surface environments. The programme will include the following environmental media:<br>  • Air<br>  • Surface and Groundwater<br>  • Soil/Sediment<br>  • Flora<br>  • Fauna<br>• The baseline monitoring would also identify the local ecosystems and potential pathways for radionuclide transport through the environment and uptake by people.<br>The requirements for sampling and analysis are described in more detail in Section 4. |

### 4.1.2 Monitoring During Operation

This section provides a summary of monitoring requirements during operation and includes the following in addition to those identified earlier:

**Table 3 Potential Environmental Effects during Operation**

| Area | Issue |
|---|---|
| **Vegetation and Flora** | |
| | Movement of radionuclides |
| | Waste water and sewage management |
| **Fauna** | |
| | Disturbance associated with human activities |
| | Movement of radionuclides |
| | Waste water and sewage management |
| | Non-radioactive waste management |
| **Socio-Economic** | |
| | Protests and demonstrations |
| | Human intrusion |

| Area | Issue |
|---|---|
| | Effects of tourists on surrounding areas |
| **Radiation** | |
| | Used fuel transport to the site |
| | Routine operations at the repository (fuel handling, repackaging, on-site transport) |

**Table 4 Environmental Monitoring Requirements during Operation**

| Issue | Monitoring Requirement |
|---|---|
| **Physical Environment** | **As for construction phase** |
| **Vegetation and Flora** | **As for construction phase plus** |
| Introduction and dispersal of weeds | • Undertake annual (spring) and opportunistic monitoring |
| Native vegetation and threatened species | • Undertake photopoint monitoring and quantitative surveys<br>• Undertake biodiversity indicator monitoring (including non-vascular plants), based upon the quantitative survey data |
| Waste water and sewage management | • Waste water to be controlled in a closed environment and disposed of appropriately to discourage weed establishment and vermin |
| Movement of radionuclides | • Radionuclide monitoring in target species |
| **Fauna** | **As for construction phase plus** |
| Waste water and sewage management | • Waste water is to be controlled in a closed environment and disposed of appropriately to discourage weed establishment and vermin |
| Non-radioactive waste management | • All waste is to be contained and disposed of off site<br>• Recyclable waste is to be separated and transported to a recycling depot or other appropriate establishment |
| Movement of radionuclides | • Radionuclide monitoring in target species<br>• Establish the existing incidence of mutations in appropriate species |
| **Socio-Economic** | |
| Protests and demonstrations | • Ongoing management of attempted unauthorised site access |
| Human intrusion | • Manage risk of human intrusion through use of security fences and surveillance |
| Effects of tourists on surrounding areas | • Monitor effects of tourist activity accessed via new road infrastructure |
| **Radiation** | |

| Issue | Monitoring Requirement |
|---|---|
| Used fuel Transport | • Monitor vehicles prior to transport from storage sites to repository<br>• Monitor environment after any transport incidents |
| Routine operations | • A monitoring programme would be established to confirm that no releases of radioactive material to the environment occur. These would include routine measurements of:<br>•Surface contamination (via instrument surveys and surface swabs)<br>•Airborne contamination (via area monitoring with high volume air-samplers and personal air samplers)<br>•External radiation dose rates (via instrument surveys).<br>• The monitoring programme would also demonstrate that environmental effects are compliant with objectives and regulatory limits<br>•The monitoring system will include both sampling of the various media as described in the baseline survey and their analysis for key contaminants and as such will cover air, surface and groundwater, biota and soil.<br>• The logistics of the sample collection and analyses would be optimised. The analyses could take place on-site or off-site. An on-site facility would require appropriate infrastructure availability.<br>• The requirements for sampling and analysis are described in more detail in Section 4. |

### 4.1.3 Monitoring During Surveillance

This section provides a summary of monitoring requirements during surveillance. Thee are essentially the same as during operations with a reduction in frequency with time. For example:

**Table 5 Environmental Monitoring Requirements during Surveillance**

| Issue | Monitoring Requirement |
|---|---|
| **Physical Environment** | |
| Surface water and erosion | • Prepare a surveillance and monitoring plan consistent with national/province policy |
| Potential for soil erosion / siltation of water courses | • Annual inspection reducing to five-yearly after five years |
| Potential for release of pollutants to soil | • Annual inspections reducing to five-yearly after five years |
| Potential for release of pollutants to surface water | • Annual inspection reducing to five-yearly after five years) |
| Potential for release of pollutants to ground water | • Annual monitoring of water levels in groundwater monitoring wells reducing to five-yearly after five years<br>• Annual groundwater sampling for pH, electrical conductivity/salinity, major ions and selected radionuclides, reducing to five-yearly after five years |
| **Radiation** | |
| Routine surveillance | • Maintain all programmes as per Operation phase |

### 4.1.4 Management and Monitoring during Decommissioning

The management and monitoring requirements during decommissioning are essentially the same as those for the operational phase.

## 4.2 ENVIRONMENTAL MONITORING PROGRAMMES

Appropriate environmental media and analytical requirements will be identified from an understanding and assessment of the site-specific characteristics and the operations at the repository. These will be based on the identification and assessment of potential release pathways and mechanisms for release of radioactive/contaminated material from the site.

It is expected that the environmental media requiring monitoring would include the following.

### 4.2.1 Airborne Particulate

Airborne particulate samples would be collected at a number of different locations around the repository site. This could be achieved using either high or low-volume continuous air samplers

which collect samples on fiberglass filter paper. The samples are typically collected at a height of 2 to 3 m. Samples are typically collected weekly and composited quarterly.

The filters would be analysed for the radionuclides, and other hazardous materials, of concern. Typically these would include analyses for actinides and fission products using alpha and gamma spectrometry. Beta analyses could also be required if releases of tritium, carbon-14 and strontium–90 were of concern. Analyses for other hazardous or toxic materials will depend on the use of, and potential releases of these, from the repository.

### 4.2.2 Soil Samples

Soil samples are typically collected at the approximate locations of air particulate sampling. The soil samples are typically collected in three depth profiles: 0-2 cm, 2-5 cm and 5-10 cm. These depth profile measurements provide information to understand the vertical migration of radionuclides.

The frequency of sampling will normally alter throughout the programme, with more frequent (monthly) sampling at the beginning of the programme moving to less frequent sampling, quarterly or yearly, with time.

The analytical measurements will address the radionuclides and hazardous/toxic materials identified to be of concern. These may be as associated with the entire soil samples or as associated with various constituents of the soil, for example the more easily leachable components or organic fraction. Such measurements can indicate the bioavailability of the compound.

### 4.2.3 Groundwater

It is anticipated that there will be a number of monitoring boreholes around the repository site. The number, and location, of these will depend on the site-specific conditions and repository design.

Observations of groundwater levels and groundwater samples will be collected on a regular basis. The frequency of sampling, and in-situ observations and measurements, will depend on the site-specific hydrogeological conditions. The groundwater samples will be analysed for both radiological and non-radiological water quality parameters.

### 4.2.4 Surface Water

Surface water samples would be collected at regular intervals from various locations in the repository vicinity. The frequency of sampling, and in-situ observations and measurements, will depend on the site-specific hydrological conditions. The surface water samples will be analysed for both radiological and non-radiological water quality parameters.

### 4.2.5 Sediments

The majority of the sediment samples would be collected at the same locations as the surface water samples. The analytical measurements of these samples will address the radionuclides

and hazardous/toxic materials identified to be of concern. These may be as associated with the entire sediment sample or as associated with various constituents of the sediment, for example the more easily leachable components or organic fraction. Such measurements can indicate the bioavailability of the compound.

### 4.2.6 Biota Samples

Uptake of radionuclides by plants and animals is an important factor in estimating the intake of radionuclides in humans through ingestion. Typically, vegetation samples are collected at the same locations that soil and air samples are taken. Fish/shellfish samples would be obtained from appropriate rivers/streams.

Animal samples would be obtained from locations adjacent to the repository site, for example, deer and rabbit samples. The appropriate species would be identified during the site characterisation phase and will typically be those who are part of the human food chain and those which might be responsible for the transfer of contaminated material throughout the environment.

## 4.3 SAMPLING AND ANALYTICAL REQUIREMENTS

The following sampling and analytical requirements will need to be defined for the environmental monitoring programme.

**1. Sampling Frequency**

This will depend on the type of media being sampled and the natural variation and cycles for that media. For example sampling could coincide with the Spring thaw and vegetation growth. Depending on the sensitivity of the analytical methods, samples might be aggregated prior to analysis.

**2. Sampling procedure**

Sampling procedures will need to be established and these should address the following:

- Equipment (e.g.soil/sediment corers, sample pots/bags)
- Conditions
    - Acidification (to prevent plating out onto the storage container walls)
    - Preservatives (to prevent decay/putrefaction)
- Storage prior to analysis
    - Light conditions

- Temperature

- Identifiers
  - Unique labelling system

**3. In-situ measurements/analysis**

Some analyses/measurement will be done on site, for example:

- External dose rate
- Oxygen concentration (of water samples)
- Turbidity
  - Gamma spectrometry

Such measurements will require the same quality control and reporting systems as described below for off-site analyses

**4. Off-site analysis**

Procedures and methodologies will need to be developed for:

- Transport and handling
- Storage
- Pretreatment
  - drying
  - ashing
  - sieving
  - filtration

**5. Analyses**

Typical analytical requirements would be:

**Water samples**

Specific conductance, total dissolved solids, total suspended solids, density, pH, Eh, specific gravity, total organic carbon, total organic halogens, chloride, alkalinity, calcium, magnesium, potassium, iron, radionuclides (e.g. Pu isotopes, Am-241, U isotopes, Cs-137, Co-60, Sr-90, C-14, H-3), heavy metals (e.g. Cd, Pb, Hg), organics (humic acids, fulvic acids, organic contaminants).

**Soil/Sediment samples**

Density, porosity, total organic matter, dry weight, wet weight, leachable fractions, radionuclides (e.g. Pu isotopes, Am-241, U isotopes, Cs-137, Co-60, Sr-90, C-14, H-3), heavy metals (e.g. Cd, Pb, Hg), organics (humic acids, fulvic acids, organic contaminants)

**Air samples**

Particulate mass, radionuclides and metals as above (and including Be-7 as a natural tracer), volatile organics if appropriate

**Flora/fauna**

Dry weight, wet weight, specific organ weights, radionuclides, heavy metals and organics as above

## 6. QA/QC

Quality assurance and quality control will be required for the entire sampling and analytical process. This will include:

- Management systems
- Method statements for all processes
- Traceability from source to result
- Replicate analyses
- Intercomparisons
- Instrument calibration
- Validation

## 7. Statistics

An approach to the analysis of results will be established. This will include:

- Data handling, trends and variances
- Treatment of outliers

**8. Records**

Records of the entire process should be established and archived.

**9. Reporting**

The results of the environmental monitoring programme should be reported as appropriate at various levels of detail and complexity.

# 5 Conclusions

The operator will be required to demonstrate, prior to the construction of the repository that there would be no adverse effect on the environment resulting from these activities. Whilst there would inevitably be much focus on the radiological components on the environment, the more conventional environmental concerns should also be addressed.

A comprehensive programme for environmental and radiation safety monitoring will be required to demonstrate that no such adverse effects were observed. This programme would be developed as part of the licensing process for the facility and in accordance with regulatory requirements.

The general objectives of environmental monitoring are to:

- establish a baseline for the repository environment prior to construction
- quantify the effect of repository operations on the environment
- demonstrate that radiation/hazardous material exposures to members of the public are compliant with objectives and that exposures are within regulatory limits
- demonstrate compliance with environmental performance objectives and regulatory limits.

The environmental monitoring programme would address physical environment, vegetation and flora, fauna, socio-economic, cultural heritage and radiation.

The sampling and analysis requirements would address, sampling frequency and procedure, in-situ measurements/analysis, off-site analysis, analyses, QA/QC, statistics, records and reporting.