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Oral presentation

Written submission from James R. Walker

Exposé oral

Mémoire de James R. Walker

In the Matter of the

À l'égard des

Canadian Nuclear Laboratories (CNL)

Laboratoires Nucléaires Canadiens (LNC)

Application from the CNL to amend its Chalk River Laboratories site licence to authorize the construction of a near surface disposal facility

Demande des LNC visant à modifier le permis du site des Laboratoires de Chalk River pour autoriser la construction d'une installation de gestion des déchets près de la surface

Commission Public Hearing Part 2

Audience publique de la Commission Partie 2

May and June 2022

Mai et juin 2022

Canada

Thank you for the opportunity to provide an intervention with respect to Canadian Nuclear Laboratories' application to amend its Chalk River Laboratories site licence to authorize the construction of a near surface disposal facility. This intervention concerns the long-term safety case.

Executive Summary

Radioactive waste is hazardous and must be kept isolated to ensure that humans and non-human biota are not exposed to unacceptable levels of radiation.

Canada has been storing radioactive waste since the 1940s. The cost of operating these radioactive waste storage facilities is not trivial — facilities must be constructed, maintained, remediated, and must be kept secure. In addition, regulatory and other societal oversight is required. The future costs associated with these human interactions (often referred to as *institutional controls*) represents a significant financial liability. If storage facilities are to be operated "in perpetuity" then the financial liability associated with the waste storage is extremely large.

A solution to the safety, cost, and liability dilemma associated with storage facilities is to construct appropriate disposal facilities. Disposal facilities are designed such that, at some point in the foreseeable future, the safety of humans and non-human biota is no longer dependant upon human intervention (maintenance, remediation, security, societal and regulatory controls, etc). At that point, the disposal of the waste has occurred, no further costs are incurred, and the financial liability is extinguished.

High level waste (HLW) has levels of activity concentration high enough to generate significant heat by radioactive decay and/or may contain large amounts of long-lived radionuclides. Disposal in deep, stable geological formations, usually several hundred metres or more below the surface, is the generally recognized option for disposal of HLW. The geosphere barrier serves to isolate humans and non-human biota from the radiological hazard over the very long time period that it will take for the radionuclides in the waste to decay to a level where they no longer represent an unacceptable risk. This is the concept being pursued by the Nuclear Waste Management Organization to dispose of Canada's used nuclear fuel.

Intermediate level waste (ILW) has, in general, a lower activity concentration than HLW and requires little or no provision for heat dissipation during its storage and disposal. However, because of its content, particularly of long lived radionuclides, it requires a greater degree of containment and isolation than that provided by near surface disposal. ILW may contain long lived radionuclides, in particular, alpha emitting radionuclides, that will not decay to a level of activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Therefore, waste in this class requires underground disposal at depths of the order of tens of metres to a few hundred metres. This is the concept that Ontario Power Generation pursued to dispose of its low-level and intermediate-level waste in its proposed Deep Geologic Repository.

Low level waste (LLW) is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods up to a few hundred years and is suitable for disposal in engineered near surface facilities. The concept of the use of a near surface disposal facility requires that the inventory of radionuclides emplaced in the near surface facility is carefully controlled so that at the end of the isolation and containment period (generally taken to be 300 years), the radionuclides emplaced in the facility will have decayed to a level where they no longer represent an unacceptable risk to humans and non-human biota. At that point, the material can be released from regulatory control, all other human interventions related to the disposal facility can cease, and the material can be abandoned. Hence, at that point (the end of the *Institutional Control Period*), the disposal of the waste has occurred, no further costs are incurred, and the financial liability is extinguished.

Canadian Nuclear Laboratories (CNL) has submitted an application for the construction of a near surface disposal facility for low level radioactive waste.

Unfortunately, CNL's proposal does not represent a disposal facility for low level radioactive waste, since:

i) the proposal is for an Engineered Containment Mound comprising a large and unverified quantity of low-level and intermediate-level radioactive waste;
ii) due to the failure to control and verify the inventory of radioactive waste emplaced, to ensure safety, the Engineered Containment Mound will require active management (security, maintenance, remediation, etc.) into the far distant future (in effect, "in perpetuity"); and
iii) the failure to control and verify the radioactive inventory prevents the financial liability from being extinguished, since disposal of the radioactive waste does not occur in the foreseeable future. The cost of the active management of the Engineered Containment Mound into the far distant future will continue to be a burden on the public purse and represents a very large long-term liability.

CNSC Staff note that their review of CNL's application has been informed by a number of Safety Standards of the International Atomic Energy Agency (IAEA) relating to the near surface disposal of radioactive waste. It is a matter of some curiosity, therefore, that CNSC Staff were not seized of the IAEA's requirement to verify the radioactive content of waste to be emplaced in a disposal facility. Similarly, it is surprising that CNSC Staff were not seized of the IAEA's prohibition on the reliance on institutional controls for extended periods of time to ensure the safety of a disposal facility.

While a disposal facility for Chalk River's low level radioactive waste is necessary, it should also comply with international safety standards.

It is an understatement to say that this proposal compares unfavourably with near surface disposal facilities in other middle-income and high-income economies such as Bulgaria, France, and Spain, for example:

https://www.enresa.es/eng/index/activities-and-projects/el-cabril ;
https://international.andra.fr/operational-facilities/csa-aube-disposal-facility ; and
http://dprao.bg/images/Annex_1_NTS_EIA_NDF_EN.pdf .

It is clear from these international examples that compliant near surface disposal facilities can be successfully designed, built, and operated.

On the face of the documents provided, there is no justification for approval of the proposed Engineered Containment Mound until the deficiencies are corrected. Given that Commission Staff have recommended approval of CNL's proposal, it would be unusual for the Commission to decline approval for the proposal.

Nevertheless, approval of this proposal may cause both Canadians and our international partners to question Canada's ability to safely manage our nuclear program and our radioactive wastes.

It is vital for Canada's reputation that our first low level waste disposal facility withstand comparison to those successfully built and operated by our international partners.

1.0 Introduction

Radioactive waste is hazardous and must be kept isolated to ensure that humans and non-human biota are not exposed to unacceptable levels of radiation.

Canada has been storing radioactive waste since the 1940s. The cost of operating these radioactive waste storage facilities is not trivial — facilities must be constructed, maintained, remediated, and must be kept secure. In addition, regulatory and other societal oversight is required. The future costs associated with these human interactions (often referred to as *institutional controls*) represents a significant financial liability. If storage facilities are to be operated "in perpetuity" then the financial liability associated with the waste storage is extremely large.

A solution to the safety, cost, and liability dilemma associated with storage facilities is to construct appropriate disposal facilities. Disposal facilities are designed such that, at some point in the foreseeable future, the safety of humans and non-human biota is no longer dependant upon human intervention (maintenance, remediation, security, societal and regulatory controls, etc). At that point, the disposal of the waste has occurred, no further costs are incurred, and the financial liability is extinguished.

High level waste (HLW) [1] has levels of activity concentration high enough to generate significant heat by radioactive decay and/or may contain large amounts of long-lived radionuclides. Disposal in deep, stable geological formations, usually several hundred metres or more below the surface, is the generally recognized option for disposal of HLW. The geosphere barrier serves to isolate humans and non-human biota from the radiological hazard over the very long time period that it will take for the radionuclides in the waste to decay to a level where they no longer represent an unacceptable risk. This is the concept being pursued by the Nuclear Waste Management Organization to dispose of Canada's used nuclear fuel.

Intermediate level waste (ILW) [1] has, in general, a lower activity concentration than HLW and requires little or no provision for heat dissipation during its storage and disposal. However, because of its content, particularly of long lived radionuclides, it requires a greater degree of containment and isolation than that provided by near surface disposal. ILW may contain long lived radionuclides, in particular, alpha emitting radionuclides, that will not decay to a level of activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Therefore, waste in this class requires underground disposal at depths of the order of tens of metres to a few hundred metres. This is the concept that Ontario Power Generation pursued to dispose of its low-level and intermediate-level waste in its proposed Deep Geologic Repository.

Low level waste (LLW) [1] is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods up to a few hundred years and is suitable for disposal in engineered near surface facilities. The concept of the use of a near surface disposal facility requires that the inventory of radionuclides emplaced in the near surface facility is carefully controlled so that at the end of the isolation and containment period (generally taken to be 300 years), the radionuclides emplaced in the facility will have decayed to a level where they no longer represent an unacceptable risk to humans and non-human biota. At that future point, the material can be released from regulatory control, all other human interventions related to the disposal facility can cease, and the material can be abandoned. Hence, at that point (the end of the *Institutional Control Period*), the disposal of the waste has occurred, no further costs are incurred, and the financial liability is extinguished.

Canadian Nuclear Laboratories (CNL) has submitted an application for the construction of a near surface disposal facility for low level radioactive waste [2]. The proposed facility is described in two Commission Member Documents prepared for a Public Hearing of the Canadian Nuclear Safety Commission (CNSC) [3, 4] and supporting documentation.

Given that the *raison d'être* for a radioactive waste disposal facility is to release the radioactive waste from regulatory and other institutional controls at a foreseeable point in the future, it is helpful to review the tolerance of radiation risks and the associated regulation of radiation exposures from materials that are under regulatory control and also from materials that are released from regulatory control.

2.0 Risk Tolerance and Radiation Exposure Regulation

2.1 Risk Tolerance

Humans, generally, do not consider actions or situations to be acceptable if the consequences of the action or situation are perceived to be particularly negative. However, humans will often accept a risk from an action or situation if the perceived benefit from the action or situation outweighs the perceived risk.

For example, a number of people are killed every year in traffic accidents. Nonetheless, the use motor vehicles is permitted since the personal and societal benefits from the use of motor vehicles are perceived to outweigh the risks.

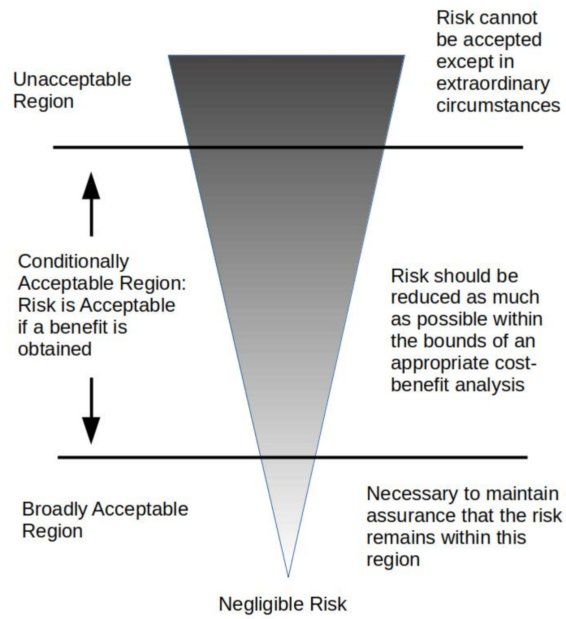
However, some behaviours involving motor vehicles are prohibited, for example, street racing, because the risk is deemed to be unacceptably high.

The "normal" use of motor vehicles is regulated to reduce the risk as much as possible while allowing the benefits of motor vehicle use to be retained, for example, by the imposition of speed limits, compulsory use of headlights, seat belts, etc.

Some activities involving motor vehicles involve negligible risks, for example having a car parked in a driveway.

This is shown schematically in Figure 1, which divides risk into the *Broadly Acceptable Region* (negligible risk), the *Conditionally Acceptable Region*, where risks should be reduced as much as possible subject to an appropriate cost-benefit analysis, and the *Unacceptable Region*, where risks cannot be accepted except in extraordinary circumstances.

Figure 1: Tolerance of Risk



The regulation of the radiation exposures for material under regulatory control and for material released from regulatory control broadly follows the scheme shown in Figure 1.

2.2 Material under Regulatory Control

The deliberations of an English charity, the International Commission on Radiological Protection (ICRP)[1], have been incorporated into the regulatory regimes of many countries around the world, including Canada.

The radiological protection principles of the ICRP are that radiation doses from regulated sources should be *justified, limited, and optimized* [5]:

- *Justification:* There need to be tangible personal or societal benefits from the exposure, such as electricity production and medical isotope production, that outweigh the harm from the exposure.
- *Limitation:* Other than medical exposures, the total dose to an individual from regulated sources should not exceed the specified dose limit.
- *Optimization:* The dose to individuals should be kept as low as reasonably achievable, taking into account economic and societal factors (ALARA).

The ICRP's recommended public dose limit of 1 mSv/year and the requirement to implement the ALARA principle are incorporated into Canada's Radiation Protection Regulations [6].

The ICRP state that the risk of cancer to a member of the public from radiological exposure is 5.5%/Sv, and that the risk of heritable effects is 0.2%/Sv, resulting in a total risk of 5.7%/Sv [5]. Hence, the public dose limit of 1 mSv/year results in an annual risk to an individual of 5.7×10^{-5}.

Application of the ALARA principle is intended to reduce this risk to a more acceptable level. The ALARA principle does not guarantee that individual members of the public will receive only very low

1 Charity Commission for England and Wales Registration Number: 1166304.

doses of radiation because it explicitly allows benefits to be judged against costs. Ultimately, this requires the regulatory body to exercise judgement with respect to the value of the benefits obtained from the regulated activity, the cost of any proposed dose reduction measure, and the value of the lives of the humans who are receiving a radiation dose as a result of the regulated activity.

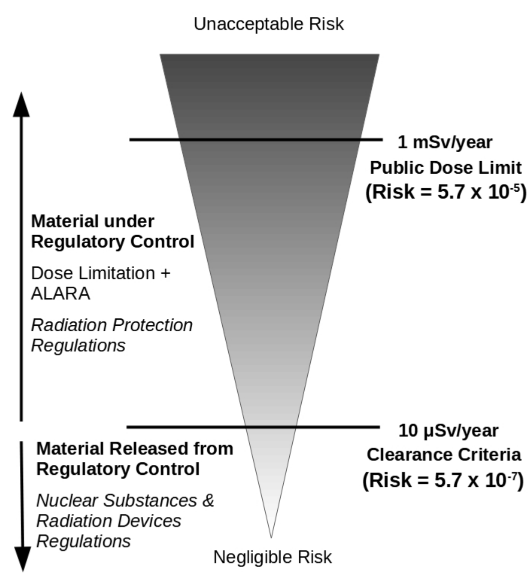
Application of this ICRP-based regulatory regime in Canada has been mostly successful in keeping radiation doses to the public from non-medical anthropogenic sources of radiation to levels well below the public dose limit.

2.3 Material released from Regulatory Control

The ICRP-based regulatory regime requires institutional controls to exist at the time of any potential radiological exposure in order to apply the *limitation* and *optimization* principles (i.e., to keep doses limited and as low as reasonably achievable).

Since the ICRP-based regulatory regime requires institutional controls to exist at the time of exposure, a different regulatory approach is required for radioactive substances that are released from regulatory control. This approach was developed by the International Atomic Energy Agency (IAEA) in applying the *clearance* concept [7], and is based on a *de minimis* (negligible risk) approach. Generally, in the IAEA’s *de minimis* approach, radioactive materials are not to be released from regulatory control unless it can be demonstrated that potential doses to individual members of the public from the released radioactive materials do not exceed 10 μSv/year. A dose of 10 μSv/year corresponds to an annual risk of 5.7 x 10^{-7}, and may be considered to be a *de minimis* dose (negligible risk).

Figure 2:Radiation Exposure Regulation



The IAEA’s *de minimis* approach to applying the clearance concept has been adopted by Canada. Canadian regulations concerning the release of radioactive materials from regulatory control and their entry into the accessible biosphere are provided in the Nuclear Substances and Radiation Devices Regulations [8]. The clearance levels (activity concentrations) given in the Nuclear Substances and Radiation Devices Regulations [8] ensure that potential doses to the public from radioactive materials released from regulatory control are limited to a maximum of 10 μSv/year.

Overall, therefore, the Canadian regulation of radiation exposures from materials that are under regulatory control and from materials that are released from regulatory control is shown schematically in Figure 2. The Public Dose Limit defines the boundary between unacceptable and conditionally acceptable radiation risks; the Clearance Level defines the boundary between conditionally acceptable radiation risks and broadly acceptable radiation risks.

2.3 Radiation Protection and Radioactive Waste Disposal

There are both ethical and practical problems in applying an ICRP-based regulatory regime to near surface radioactive waste disposal.

From the perspective of a person alive after the end of the Institutional Control Period (e.g., 300 years in the future), it is not possible to apply the ICRP principle of *justification* when there are no personal nor societal benefits from the exposure, and any benefits that may have been received were received 300 years in the past. Similarly, the principles of *limitation* and *optimization* cannot be applied, as there will, by definition, be no institutional controls available.

In recognition of the problems associated with applying their regulatory regime to radioactive waste disposal, the ICRP states that [9]:

> Formal optimisation techniques for application to potential exposure remain to be developed as emphasised in the following ICRP publications:
>
> - Publication 64 (ICRP 1993, paragraph 84): "Disposal of radioactive waste leads to a radiation source which may extend over extremely long periods. This poses methodological problems connected with the assignment of probabilities to events and processes for potential exposure assessment."
> - Publication 76 (ICRP 1997a, paragraph 62): "Optimisation of protection against potential exposure is still largely unresolved, particularly when probabilities are low and consequences are big."
> - Publication 77 (ICRP 1997b, paragraph 27 d): "The role of potential exposure in risk assessment for long-lived radionuclides is not yet clear."[2]

For the disposal of long-lived radioactive waste, the ICRP has recommended that 0.3 mSv be used as a constraint on public exposures from a waste disposal facility as it evolves under "natural processes" [9]. In making this recommendation, they note that shallow land burial in trenches, engineered facilities, or via *in situ* stabilization is appropriate only for short-lived radionuclides because of the risk of inadvertent human intrusion or loss of containment due to natural processes [9].

Given the ethical and practical problems in applying an ICRP-based regulatory regime to radioactive waste disposal once institutional controls have terminated, a *de minimis* (clearance) approach is warranted, for example:

2 ICRP publications *ICRP 1993*, *ICRP 1997a*, and *ICRP 1997b* are, respectively, references [10], [11] and [12] in this text.

1) The Nuclear Substances and Radiation Devices Regulations [8] state the following:

> **Abandonment or Disposal**
>
> 5.1 (1) A person may, without a licence, abandon or dispose of a radioactive nuclear substance if the activity or the activity concentration of the substance does not exceed
> (a) its exemption quantity;
> (b) its conditional clearance level; or
> (c) its unconditional clearance level.
> (2) Subsection (1) does not apply in respect of
> (a) Category I nuclear material, Category II nuclear material or Category III nuclear material, as those terms are defined in section 1 of the *Nuclear Security Regulations*; or
> (b) discharges of effluents from
> (i) Class I nuclear facilities, as defined in section 1 of the *Class I Nuclear Facilities Regulations*, or
> (ii) mines or mills, as those terms are defined in section 1 of the *Uranium Mines and Mills Regulations*.

2) In evaluating the Canadian Nuclear Fuel Waste Management Program [13], the Atomic Energy Control Board required that [14]:

> The predicted radiological risk to individuals from a waste disposal facility shall not exceed 10^{-6} fatal cancers and serious genetic effects in a year, calculated without taking advantage of long-term institutional controls as a safety feature.

3) The United Kingdom has published requirements for the management of radioactive waste from decommissioning sites [15]. For the predicted normal evolution of the waste facility, the requirements allow the use of the ICRP’s 0.3 mSv dose constraint ***only*** during the period of institutional control. Subsequent to the Institutional Control Period, an individual risk of 10^{-6} per year should be used [15]:

> Operators should demonstrate through the SWESC[3] that, after release from radioactive substances regulation, the assessed risk from the remaining radiological hazards to a representative person should be consistent with a risk guidance level of 10^{-6} per year (that is, a risk of death or heritable defect of 1 in a million per year due to exposure to ionising radiation).

3 Site-wide Environmental Safety Case.

3.0 CNL's Proposed Engineered Containment Mound

The management of the radionuclide inventory and the length of time until the radioactive material is released from regulatory control is critical to the safety of any near surface radioactive waste disposal facility.

3.1 Radioactive Inventory

Neither of the substantive Commission Member Documents prepared for the Day 1 Public Hearing [3, 4] contained detailed information on the radionuclide inventory of the proposed Engineered Containment Mound.

However, CNL's Environmental Impact Statement [16] contains, in Table 3.3.1-2, a "Reference Inventory" and a "Licensed Inventory". Table 3.3.1-2 of CNL's Environmental Impact Statement is reproduced in this intervention as Table 1.

Table 1: Reference Inventory and Licensed Inventory of the Engineered Containment Mound (After Table 3.3.1-2 of [16])

Radionuclide	Half Life (years)	Predominant Decay Emission	Reference Inventory		Licensed Inventory	
			Total Activity (Bq) at Emplacement	Total Activity (Bq) at Closure	Maximum Activity (Bq) at Placement	Maximum Activity (Bq) at Closure
Silver-108m	438	gamma	2.73×10^{10}	2.62×10^{10}	2.73×10^{10}	2.62×10^{10}
Americium-241	433	alpha/gamma	6.04×10^{10}	9.74×10^{10}	6.04×10^{10}	9.74×10^{10}
Americium-243	7,360	alpha	5.26×10^{7}	5.24×10^{7}	5.26×10^{7}	5.24×10^{7}
Carbon-14	5,700	beta	1.71×10^{12}	1.70×10^{12}	1.71×10^{12}	1.70×10^{12}
Chlorine-36	301,000	beta	3.97×10^{9}	3.97×10^{9}	3.97×10^{9}	3.97×10^{9}
Cobalt-60	5	beta/gamma	9.06×10^{16}	1.47×10^{16}	9.06×10^{16}	1.47×10^{16}
Cesium-135	2,300,000	beta	5.19×10^{8}	5.19×10^{8}	5.19×10^{8}	5.19×10^{8}
Cesium-137	30	beta/gamma	5.59×10^{12}	3.17×10^{12}	5.59×10^{12}	3.17×10^{12}
Hydrogen-3 (Tritium)	12	beta	8.91×10^{14}	2.79×10^{14}	8.91×10^{14}	2.79×10^{14}
Iodine-129	15,700,000	beta/gamma/x-ray	3.03×10^{10}	3.03×10^{10}	1.75×10^{10}	1.75×10^{10}
Molybdenum-93	4,000	x-ray	1.47×10^{5}	1.47×10^{5}	1.47×10^{5}	1.47×10^{5}
Niobium-94	20,300	beta/gamma	2.34×10^{10}	2.34×10^{10}	2.34×10^{10}	2.34×10^{10}
Nickel-59	76,000	x-ray	1.21×10^{9}	1.21×10^{9}	1.21×10^{9}	1.21×10^{9}
Nickel-63	101	beta	3.11×10^{11}	2.59×10^{11}	3.11×10^{11}	2.59×10^{11}
Neptunium-237	2,140,000	alpha/gamma	1.74×10^{7}	1.74×10^{7}	1.74×10^{7}	1.74×10^{7}
Plutonium-239	24,100	alpha	8.77×10^{10}	8.76×10^{10}	5.07×10^{10}	5.06×10^{10}
Plutonium-240	6,650	alpha				
Plutonium-241	14	beta	1.67×10^{12}	5.84×10^{11}	1.67×10^{12}	5.84×10^{11}
Plutonium-242	375,000	alpha	6.32×10^{07}	6.32×10^{7}	6.32×10^{7}	6.32×10^{7}
Radium-226	1,600	alpha/gamma	3.65×10^{10}	3.61×10^{10}	3.65×10^{10}	3.61×10^{10}

Selenium-79	327,000	beta	9.26×10^{7}	9.26×10^{7}	9.26×10^{7}	9.26×10^{7}
Tin-126	230,000	beta/gamma	1.24×10^{8}	1.24×10^{8}	1.24×10^{8}	1.24×10^{8}
Strontium-90	29	beta	6.05×10^{12}	3.35×10^{12}	6.05×10^{12}	3.35×10^{12}
Technetium-99	211,000	beta	3.16×10^{11}	3.16×10^{11}	3.16×10^{11}	3.16×10^{11}
Thorium-230	75,400	alpha	5.30×10^{9}	5.30×10^{9}	5.30×10^{9}	5.30×10^{9}
Thorium-232	14,000,000,000	alpha	2.70×10^{10}	2.70×10^{10}	2.70×10^{10}	2.70×10^{10}
Uranium-233	159,000	alpha	2.74×10^{8}	2.74×10^{8}	2.74×10^{8}	2.74×10^{8}
Uranium-234	246,000	alpha	6.88×10^{10}	6.88×10^{10}	6.88×10^{10}	6.88×10^{10}
Uranium-235	704,000,000	alpha/gamma	2.96×10^{9}	2.96×10^{9}	2.96×10^{9}	2.96×10^{9}
Uranium-238	4,470,000,000	alpha/gamma	7.57×10^{10}	7.57×10^{10}	7.57×10^{10}	7.57×10^{10}
Zirconium-93	1,610,000	beta	4.92×10^{11}	4.92×10^{11}	4.92×10^{11}	4.92×10^{11}

3.2 Design Life

It is a basic tenet of safety analysis methodology that the safety performance of a safety-related system should not be credited if the design life of the structures, systems, and components that comprise the safety-related system has been exceeded. The design life of the Engineered Containment Mound is stated to be 550 years. It is, perhaps, useful to calculate what remains of the Licensed Inventory at the end of the design life (Table 2).

Table 2: Remaining Radiological Inventory of the Engineered Containment Mound at the end of the Design Life

Radionuclide	Half Life (years)	Predominant Decay Emission	Maximum Activity (Bq) at Closure (Licensed Inventory)	Maximum Activity (Bq) at End of Design Life
Silver-108m	438	gamma	2.62×10^{10}	1.10×10^{10}
Americium-241	433	alpha/gamma	9.74×10^{10}	4.04×10^{10}
Americium-243	7,360	alpha	5.24×10^{7}	4.98×10^{7}
Carbon-14	5,700	beta	1.70×10^{12}	1.59×10^{12}
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Cobalt-60	5	beta/gamma	1.47×10^{16}	1.13×10^{-17}
Cesium-135	2,300,000	beta	5.19×10^{8}	5.19×10^{8}
Cesium-137	30	beta/gamma	3.17×10^{12}	9.60×10^{6}
Hydrogen-3 (Tritium)	12	beta	2.79×10^{14}	4.45×10^{0}
Iodine-129	15,700,000	beta/gamma/x-ray	1.75×10^{10}	1.75×10^{10}
Molybdenum-93	4,000	x-ray	1.47×10^{5}	1.34×10^{5}
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Zirconium-93	1,610,000	beta	4.92×10^{11}	4.92×10^{11}

As can be seen from Table 2, the short-lived radionuclides (notably Co-60, Cs-137, Tritium, Pu-241, Sr-90) have decayed appreciably by the end of the design life. On the other hand, many other radionuclides (notably C-14, I-129, Tc-99, most actinides) have not decayed to any appreciable extent.

Of course, the definition of low level waste allows for limited quantities of long lived radionuclides [1]. However, the quantity of long lived radionuclides must be controlled so that the radionuclide inventory does not represent an unacceptable risk when the material is released from regulatory control. It is necessary, therefore, to review the waste acceptance criteria for the Engineered Containment Mound to determine whether the quantity of long lived radionuclides is problematic.

3.3 Waste Acceptance

The radiological parameters of the Waste Acceptance Criteria (WAC) for the Engineered Containment Mound were not detailed in reference [3] and were only partially detailed in reference [4]. The full details of the radiological parameters of the Waste Acceptance Criteria for the Engineered Containment Mound were, however, detailed in Table 3.3.3-1 of CNL’s Environmental Impact Statement [16] and that table is reproduced in this intervention as Table 3.

Table 3: Radionuclide Concentration Limits in the Engineered Containment Mound (After Table 3.3.1-1 of [16])

Limits for Bulk Waste & Non-Leachate Controlled Waste Packaged Waste	■ 100 Bq/g for alpha emitting radionuclides ■ 1,000 Bq/g for long-lived beta/gamma emitting radionuclides (half life >cesium-137) ■ 10,000 Bq/g for short-lived beta/gamma emitting radionuclides (half life ≤ cesium-137) ■ 100,000 Bq/g for tritium
Limits for Leachate Controlled Packaged Waste	■ 400 Bq/g for alpha emitting radionuclides ■ 10,000 Bq/g for long-lived beta/gamma emitting radionuclides (half life >cesium-137) ■ 10,000 Bq/g for cesium-137 ■ 10,000 Bq/g for strontium-90 ■ 10,000,000 Bq/g for tritium

It is clear from Table 3 that a number of radionuclides of importance in assessing the safety of near surface waste disposal facilities, for example the beta-emitting radioisotopes C-14 and Tc-99, have significant inventories listed in Table 1 and are not captured by the waste acceptance criteria for the Engineered Containment Mound.

The requirements of IAEA Safety Standards with respect to waste acceptance and verification require, *inter alia*, that

- Waste packages and unpackaged waste accepted for emplacement in a disposal facility shall conform to criteria that are fully consistent with, and are derived from, the safety case for the disposal facility in operation and after closure [17];
- Waste intended for near surface disposal should be characterized to provide sufficient information to ensure compliance with waste acceptance criteria. Arrangements should be put into place to verify that the waste and waste packages received for disposal comply with these criteria, and if not, to ensure that corrective measures will be taken by the responsible party, either the waste generator or the operator of the disposal facility... [18];
- ... specific aspect that should be considered is the requirement to ensure appropriate limitation of the waste inventory in terms of the activity, mainly of long lived radionuclides, that can be disposed of. A waste acceptance process should therefore be put in place that integrates all elements (waste characterization, and a management system for the waste acceptance for disposal) that are necessary to ensure that this limitation is complied with during waste emplacement activities [18]; and
- The following aspects warrant particular consideration in developing a management system for radioactive waste management ... the need to ensure ... that waste packages and unpackaged waste conform to the waste acceptance criteria of the receiving organization ... [19].

Given these requirements, one might have expected that CNL's proposal would have included a "waste reception and verification facility", with appropriate technical equipment and management system, to verify compliance with the stated acceptance criteria. However, this does not appear to form part of the proposal. A review of the available documentation does not reveal a technical capability, nor an associated management system, to comprehensively verify that waste packages and unpackaged waste accepted for emplacement comply with the radiological parameters of the stated waste acceptance criteria.

It is difficult to give credence to any assessment of doses to the public from the proposed Engineered Containment Mound when the Waste Acceptance Criteria does not cover all of the radionuclides of importance in assessing the safety of near surface disposal facilities and where there is inadequate verification of the radioactive content of the mound.

3.4 Time to Reach Disposal Criteria

Humans are adept at reusing waste materials, sometimes with undesirable consequences. Radioactive materials that were not under appropriate institutional controls have been scavenged to obtain metals, construction materials, and other items of value, for example at Port Hope, Ontario [20], Semiplatinsk, Kazakhstan [21], and Goiânia, Brazil [22]. Such scavenging activities have resulted in costly remediation, excessive radiation exposures, and deaths. Near surface disposal facilities are particularly susceptible to scavenging activities as they are located in the biosphere and, hence, are easily accessible. Therefore it is important to ensure that both packaged and bulk radioactive waste will have decayed to an appropriate level prior to release from institutional controls.

It is stated in [3] and [16] that the maximum doses to persons from the Engineered Containment Mound are 0.015 mSv and 0.14 mSv, for the normal evolution and disruptive events, respectively. These maximum doses occur at 4,100 years and 7,650 years, respectively, both of which are significantly beyond the design life of the Engineered Containment Mound.

The stated doses of 0.015 mSv and 0.14 mSv are both above the criteria used by our international partners (See Section 2.3) and are non-compliant with the criteria for disposal given in Canadian regulations [8].

Hence, even using the stated inventory of the Engineered Containment Mound (Table 1), the radionuclides have not decayed sufficiently to meet disposal criteria even after several thousand years.

It is possible to calculate how long it would take for waste at the limits provided by the stated waste acceptance criteria to decay to the unconditional clearance criteria given in the Nuclear Substances and Radiation Devices Regulations [8]. These calculations are given in Table 4. For simplicity, only radionuclides that are unambiguously captured by the stated waste acceptance criteria are included, and only the limits for "leachate-controlled" packaged waste are given in the table.

Table 4: Time to Reach Unconditional Clearance Levels for Radionuclides in the Radioactive Inventory of the Engineered Containment Mound

Radionuclide	Half Life (years)	Predominant Decay Emission	Maximum Activity (Bq) at Closure (Licensed Inventory)	WAC Concentration Limit (Bq/g) (Leachate Controlled, Packaged Waste)	Unconditional Clearance Criteria (Bq/g) [8]	Time to reach Unconditional Clearance level (years)
Silver-108m	438	gamma	2.62×10^{10}			
Americium-241	433	alpha/gamma	9.74×10^{10}	400	0.1	5181
Americium-243	7,360	alpha	5.24×10^{7}	400	0.1	88,068
Carbon-14	5,700	beta	1.70×10^{12}			
Chlorine-36	301,000	beta	3.97×10^{9}			
Cobalt-60	5	beta/gamma	1.47×10^{16}			
Cesium-135	2,300,000	beta	5.19×10^{8}			
Cesium-137	30	beta/gamma	3.17×10^{12}	10,000	0.1	498
Hydrogen-3 (Tritium)	12	beta	2.79×10^{14}	10,000,000	100	199
Iodine-129	15,700,000	beta/gamma/x-ray	1.75×10^{10}	10,000	0.01	3.13×10^{8}
Molybdenum-93	4,000	x-ray	1.47×10^{5}			
Niobium-94	20,300	beta/gamma	2.34×10^{10}	10,000	0.1	3.37×10^{5}
Nickel-59	76,000	x-ray	1.21×10^{9}			
Nickel-63	101	beta	2.59×10^{11}			
Neptunium-237	2,140,000	alpha/gamma	1.74×10^{7}	400	1	1.85×10^{7}
Plutonium-239	24,100	alpha	5.06×10^{10}	400	0.1	2.88×10^{5}
Plutonium-240	6,650	alpha	5.06×10^{10}	400	0.1	79,572
Plutonium-241	14	beta	5.84×10^{11}			
Plutonium-242	375,000	alpha	6.32×10^{7}	400	0.1	4.49×10^{6}
Radium-226	1,600	alpha/gamma	3.61×10^{10}	400	1	13,830
Selenium-79	327,000	beta	9.26×10^{7}			
Tin-126	230,000	beta/gamma	1.24×10^{8}	10,000	1	3.06×10^{6}
Strontium-90	29	beta	3.35×10^{12}	10,000	1	385
Technetium-99	211,000	beta	3.16×10^{11}			
Thorium-230	75,400	alpha	5.30×10^{9}	400	1	6.52×10^{5}
Thorium-232	14,000,000,000	alpha	2.70×10^{10}	400	1	1.21×10^{11}
Uranium-233	159,000	alpha	2.74×10^{8}	400	1	1.37×10^{6}
Uranium-234	246,000	alpha	6.88×10^{10}	400	1	2.13×10^{6}
Uranium-235	704,000,000	alpha/gamma	2.96×10^{9}	400	1	6.09×10^{9}
Uranium-238	4,470,000,000	alpha/gamma	7.57×10^{10}	400	1	3.86×10^{10}
Zirconium-93	1,610,000	beta	4.92×10^{11}			

As can be seen from Table 4, even without performing the sum-of-fractions calculation required by the regulations [8], it is a very long time before many of the radionuclides, at the limit specified in the waste acceptance criteria, decay to the limit specified in the Canadian regulations for disposal.

Hence, the stated waste acceptance criteria are insufficiently protective for the material permitted to be emplaced in the proposed Engineered Containment Mound to qualify as low level waste — the radionuclides do not decay to an acceptable level during the time that institutional controls can be relied upon. Consequently, the emplaced material is intermediate level radioactive waste that requires a greater degree of containment and isolation than that provided by a near surface facility [1].

3.5 Institutional Control Period

The *raison d'être* for a radioactive waste disposal facility is that, at some point in the foreseeable future, the safety of humans and non-human biota is no longer dependant upon human intervention (maintenance, remediation, security, societal and regulatory controls, etc). At that point, the radioactive waste can be released from regulatory and other institutional controls, the disposal of the waste will have occurred, no further costs will be incurred, and the financial liability will be extinguished.

IAEA Safety Standards SSR-5 [17], *Disposal of Radioactive Waste,* and SSG-29 [18], *Near Surface Disposal Facilities for Radioactive Waste,* state that:

> The long term safety of a disposal facility for radioactive waste has not to be dependent on active institutional control.

Since institutional controls can only be relied upon for a certain period of time (generally taken to be 300 years), partly because of the fragility of human society, this places a limit on the length of any Institutional Control Period that can be credited in the safety case of a near surface disposal facility.

Given the relationship between the expected duration of institutional controls and the period of time over which long lived waste will remain hazardous led the IAEA, in SSG-23 [23], *The Safety Case and Safety Assessment for the Disposal of Radioactive Waste,* to note the following:

> In the disposal of radioactive waste at or near the surface, institutional control is usually required for achieving the safety objective and should remain in place as long as the waste remains potentially hazardous (e.g. a few hundred years). Waste containing appreciable amounts of long lived radionuclides should be disposed of at greater depths. Assumptions concerning the duration of institutional control play a major role in defining waste acceptance criteria, particularly for near surface disposal facilities.

Consequently, one might have expected details to be presented on why it was considered safe to release the Engineered Containment Mound from regulatory and other institutional controls at the end of the Institutional Control Period.

Regrettably, no such arguments are presented in the documentation to demonstrate that the Engineered Containment Mound is safe to be released from regulatory and other institutional controls at the end of the Institutional Control Period (which is stated to be 300 years).

Instead it is left to a postulated future regulator in the indefinitely-long "Post-Institutional Control Period" to decide when the Engineered Containment Mound can be released from regulatory control (and the liability extinguished). As this future regulator is postulated to exist in a period beyond the time that institutional controls can be relied upon, it is difficult to see how the actions of this future regulator can be credited in a safety case. Similarly, given that there is no system in place to verify compliance with the waste acceptance criteria and given that a number of significant radionuclides are not captured by the waste acceptance criteria, it is difficult to understand how the postulated future regulator could make an informed judgement on releasing the Engineered Containment Mound from regulatory control.

3.6 Technical Observations

The technical deficiencies in the proposed Engineered Containment Mound are disappointing:

- Many radionuclides in the Licensed Inventory will have experienced insignificant amounts of radioactive decay by the end of the design life of the Engineered Containment Mound;
- Many radionuclides of importance in assessing the safety of near surface disposal facilities, e.g., C-14 and Tc-99, are present in the Licensed Inventory in significant quantities but are not captured by the waste acceptance criteria;
- No inventory management system is in place to comprehensively verify that waste packages and unpackaged waste accepted for emplacement comply with the radiological parameters of the stated waste acceptance criteria;
- The waste acceptance criteria are insufficiently protective for the material permitted to be emplaced in the proposed Engineered Containment Mound to qualify as low level waste — the radionuclides do not decay to an acceptable level during the time that institutional controls can be relied upon. Consequently, the emplaced material is intermediate level radioactive waste that should not be emplaced in a near surface facility because it requires a greater degree of containment and isolation than that provided by near surface disposal;
- The future safety of Canadians is dependent upon the actions of a postulated future regulator in the indefinitely-long "Post-Institutional Control Period" to decide when the Engineered Containment Mound can be released from regulatory control (and the liability extinguished). As this future regulator is postulated to exist in a period beyond the time that institutional controls can be relied upon, the reliance on the actions of this postulated future regulator is problematical.
- Further, given that there is no system in place to verify compliance with the waste acceptance criteria and given that a number of significant radionuclides are not captured by the waste acceptance criteria, it is difficult to understand how the postulated future regulator could make an informed judgement on releasing the Engineered Containment Mound from regulatory control.

4.0 Concluding Remarks

Radioactive waste is hazardous and must be kept isolated to ensure that humans and non-human biota are not exposed to unacceptable levels of radiation.

Canadian Nuclear Laboratories (CNL) has submitted an application for the construction of a near surface disposal facility for low level radioactive waste.

Unfortunately, CNL's proposal does not represent a disposal facility for low level radioactive waste, since:

i) the proposal is for an Engineered Containment Mound comprising a large and unverified quantity of low-level and intermediate-level radioactive waste;
ii) due to the failure to control and verify the inventory of radioactive waste emplaced, to ensure safety, the Engineered Containment Mound will require active management (security, maintenance, remediation, etc.) into the far distant future (in effect, "in perpetuity"); and
iii) the failure to control and verify the radioactive inventory prevents the financial liability from being extinguished, since disposal of the radioactive waste does not occur in the foreseeable future. The cost of the active management of the Engineered Containment Mound into the far distant future will continue to be a burden on the public purse and represents a very large long-term liability.

CNSC Staff note that their review of CNL's application has been informed by a number of Safety Standards of the International Atomic Energy Agency (IAEA) relating to the near surface disposal of radioactive waste. It is a matter of some curiosity, therefore, that CNSC Staff were not seized of the IAEA's requirement to verify the radioactive content of waste to be emplaced in a disposal facility. Similarly, it is surprising that CNSC Staff were not seized of the IAEA's prohibition on the reliance on institutional controls for extended periods of time to ensure the safety of a disposal facility.

While a disposal facility for Chalk River's low level radioactive waste is necessary, it should also comply with international safety standards.

It is an understatement to say that this proposal compares unfavourably with near surface disposal facilities in other middle-income and high-income economies such as Bulgaria, France, and Spain, for example:

https://www.enresa.es/eng/index/activities-and-projects/el-cabril ;
https://international.andra.fr/operational-facilities/csa-aube-disposal-facility ; and
http://dprao.bg/images/Annex_1_NTS_EIA_NDF_EN.pdf .

It is clear from these international examples that compliant near surface disposal facilities can be successfully designed, built, and operated.

On the face of the documents provided, there is no justification for approval of the proposed Engineered Containment Mound until the deficiencies are corrected. Given that Commission Staff have recommended approval of CNL's proposal, it would be unusual for the Commission to decline approval for the proposal.

Nevertheless, approval of this proposal may cause both Canadians and our international partners to question Canada's ability to safely manage our nuclear program and our radioactive wastes.

It is vital for Canada's reputation that our first low level waste disposal facility withstand comparison to those successfully built and operated by our international partners.

5.0 References

[1] International Atomic Energy Agency, *Classification of Radioactive Waste,* General Safety Guide GSG-1, 2009.

[2] Letter from P. Boyle (CNL) to M. Leblanc (CNSC), *Updated Application for Licence Amendment to add the Near Surface Disposal Facility to the Chalk River Laboratories Licensing Basis,* 232-CNNO-21-0004-L, 2021 March 26.

[3] Canadian Nuclear Safety Commission, *A Licence Amendment, Required Approvals for Construction of the Near Surface Disposal Facility (NSDF) at the Chalk River Laboratories (CRL) site,* CMD 22-H7, 2022 January 24.

[4] Canadian Nuclear Laboratories, *Chalk River Laboratories Site Licence Amendment to Authorize the Construction of the Near Surface Disposal Facility,* 232-508760-REPT-002, CMD 22-H7.1, 2022 January 24.

[5] International Commission on Radiological Protection, *ICRP Publication 103: The 2007 Recommendations of the International Commission on Radiological Protection,* 2007.

[6] Canada, *Radiation Protection Regulations,* SOR/2000-203.

[7] International Atomic Energy Agency, *Application of the Concepts of Exclusion, Exemption and Clearance,* IAEA Safety Standards Series, Safety Guide RS-G-1.7, 2004.

[8] Canada, *Nuclear Substances and Radiation Devices Regulations,* SOR/2000-207.

[9] International Commission on Radiological Protection, *ICRP Publication 81: Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste*, 1998.

[10] International Commission on Radiological Protection, *Protection from Potential Exposure: A Conceptual Framework*, ICRP Publication 64, 1993.

[11] International Commission on Radiological Protection, *Protection from Potential Exposures: Application to Selected Radiation Sources,* ICRP Publication 76, 1997.

[12] International Commission on Radiological Protection, *Radiological Protection Policy for the Disposal of Radioactive Waste,* ICRP Publication 77, 1997.

[13] Atomic Energy of Canada Limited, *Environmental Impact Statement on the Concept for Disposal of Canada’s Nuclear Fuel Waste,* AECL-10711, COG-93-1, 1994.

[14] Atomic Energy Control Board, *Regulatory Objectives, Requirements and Guidelines for the Disposal of Radioactive Waste — Long-Term Aspects,* R-104, 1987.

[15] Scottish Environmental Protection Agency, Environment Agency, Natural Resources Wales, *Management of Radioactive Waste from Decommissioning of Nuclear Sites: Guidance on Requirements for Release from Radioactive Substances Regulation, Version 1.0,* 2018.

[16] Canadian Nuclear Laboratories, *NSDF Environmental Impact Statement,* 232-509220-REPT-004, Revision 3, 2021.

[17] International Atomic Energy Agency, *Disposal of Radioactive Waste*, Specific Safety Requirements SSR-5, 2011.

[18] International Atomic Energy Agency, *Near Surface Disposal Facilities for Radioactive Waste,* Specific Safety Guide SSG-29, 2014.

[19] International Atomic Energy Agency, *Leadership, Management and Culture for Safety in Radioactive Waste Management,* General Safety Guide SSG-16, 2022.

[20] Natural Resources Canada, Canadian Nuclear Safety Commision, Fisheries and Oceans Canada, *Screening Report, The Port Hope Long-Term Low-Level Waste Management Project*, 2006.

[21] *Plutonium Mountain*, *Inside the 17-year mission to secure a dangerous legacy of Soviet nuclear testing*, Eben Harrell & David E. Hoffman, Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, 2013.

[22] International Atomic Energy Agency, *The Radiological Accident in Goiânia,* ISBN 92-0-129088-8, 1988.

[23] International Atomic Energy Agency, *The Safety Case and Safety Assessment for the Disposal of Radioactive Waste,* Specific Safety Guide SSG-23, 2012.