A COMPARATIVE ANALYSIS OF MANAGING RADIOACTIVE WASTE IN THE CANADIAN NUCLEAR AND NON-NUCLEAR INDUSTRIES

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ABSTRACT

Management of radioactive waste in nuclear industries in Canada is tightly regulated. The regulated nuclear industries include nuclear power generation, uranium mining and milling, nuclear medicine, radiation research and education and industrial users of nuclear material (e.g. radiography, thickness gauges, etc).

In contrast, management of Naturally Occurring Radioactive Material (NORM) waste is not regulated by the Canadian Nuclear Safety Commission (CNSC), with the exception of transport above specified concentrations. Although these are radioactive materials that have always been present in various concentrations in the environment and in the tissues of every living animal, including humans, the hazards of similar quantities of NORM radionuclides are identical to those of the same or other radionuclides from regulated industries. The concentration of NORM in most natural substances is so low that the associated risk is generally regarded as negligible, however higher concentrations may arise as the result of industrial operations such as:

- oil and gas production
- mineral extraction and processing (e.g. phosphate fertilizer production)
- metal recycling
- thermal electric power generation
- water treatment facilities

Health Canada has published the *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)*. This paper presents a comparative analysis of the requirements for management of radioactive waste in the regulated nuclear industries and of the guidelines for management of NORM waste.

1. MANAGING RADIOACTIVE WASTE IN THE CANADIAN NUCLEAR INDUSTRIES

Management of radioactive waste in the nuclear industries is regulated by the CNSC. Numerous regulations, standards and guides apply, including (but not limited to):

- CNSC Nuclear Safety and Control Act [1]
- CNSC General Nuclear Safety and Control Regulations [2]
- CNSC Nuclear Security Regulations [3]
- CNSC Nuclear Substances and Radiation Devices Regulations [4]
- CNSC Class I Nuclear Facilities Regulations [5] (potentially)
- CNSC Packaging and Transport of Nuclear Substances Regulations [6]

- CNSC Regulatory Policy P-290 – Managing Radioactive Waste [7]
- CNSC Regulatory Guide G–320 - Assessing the Long Term Safety of Radioactive Waste Management [8]
- Canadian Standards Association (CSA) N292.3-08 - Management of Low- and Intermediate-Level Radioactive Waste [9]

Safety assessments, environmental assessments and public consultation may be required before a CNSC license can be issued for the work to commence.

1.1 Managing Contaminated Materials at Nuclear Power Plants

If contaminated soil or construction materials waste arises during excavation or clearing for construction purposes of an area on-site at a CNSC licensed nuclear power generating facility and the waste requires off-site disposal, the following steps would be followed:

1. Conduct a review to identify potential radiological and non-radiological contaminants in the material based on its history within the facility (e.g. location, process system, etc.).
2. Conduct a radiological survey of the area/material.
3. Develop a radiological and non-radiological sampling and analysis characterisation plan in accordance with international standards (e.g. ISO, ASTM, ANSI) to ensure representativeness and statistical accuracy.
4. Conduct the sampling and analysis. In order to release the waste with no restrictions, the results of the characterisation of the waste have to meet the requirements of the unconditional clearance levels in the CNSC Nuclear Substances and Radiation Devices Regulations (NSRDR) [4], which are based on a 10 μSv annual dose criterion for members of the public. They also have to meet Provincial and Federal regulations for conventional contaminants.
5. On the basis of the results of the characterisation of the waste, assuming the unconditional clearance levels have not been exceeded and there are no non-radiological restrictions, the mode of disposition, such as disposal, recycling or reuse can be determined.
6. If the unconditional clearance criteria are not met, the material may still be eligible for conditional clearance subject to CNSC approval of a site-specific and end-use specific risk assessment.
7. If the criteria for either unconditional or conditional clearance have not been met then re-examination of the waste would be required to determine whether the contaminated portion of the waste can be effectively isolated and removed thus rendering the remaining material eligible for clearance.
8. If the material cannot be cleared then it has to be packaged appropriately and sent to a licensed radioactive waste storage facility.
9. If the unconditional clearance criteria are met then a plan for disposal or other disposition of the material has to be prepared. All of the relevant documentation has to be kept for Quality Assurance purposes and CNSC could be provided with the plan for information. From the point of view of CNSC regulatory requirements, there are no further restrictions.
10. For cleared waste, assuming disposal at non-hazardous municipal landfill has been chosen as the preferred disposal route, it is necessary to identify a suitable landfill. The facility has to meet all provincial and municipal regulations and it must be prepared to accept the waste.

11. It is necessary to verify whether the landfill's certificate of approval or licence contain any clauses or restrictions on radioactivity in waste and these additional criteria would have to be satisfied. Even a requirement for approval by the landfill's Advisory Committee may be an impediment if there is concern about receiving any waste from a nuclear site. An additional practical problem is that even cleared material may trigger an alarm at very sensitive portal monitors used at landfills, which may result in rejection of the waste.

1.2 The Port Hope Long-Term Low-Level Radioactive Waste Management Project

Low-level radioactive waste and 'marginally contaminated' soils in the Municipality of Port Hope resulted from industrial activities associated with radium refining dating back to 1933. Process residues and wastes were placed at various locations in the community, including at the Port Hope landfill, and used as a source of fill material for construction and landscaping activities.

The focus of ore processing shifted to uranium in the 1940s. In 1948, transfer of waste to the Welcome Waste Management Facility (WMF) commenced. The Welcome WMF operated until 1955, at which time a new waste management site was established near the hamlet of Port Granby in Clarington.

Between 1976 and 1981, remedial actions were performed at residential and commercial properties and approximately 100,000 tonnes of radioactively contaminated soil was transferred to a WMF at AECL's Chalk River Laboratories site. Contaminated soil in vacant areas and the sediments in Port Hope Harbour were left in place for cleanup at a later date.

The current Port Hope Long-Term Low-Level Radioactive Waste Management Project consists of remediation of these remaining areas and transfer of associated waste, together with the waste in the existing WMFs, to a new long-term WMF designed to modern standards. The new WMF will consist of engineered liners and caps to prevent long-term migration of radioactive material (Figure 1).

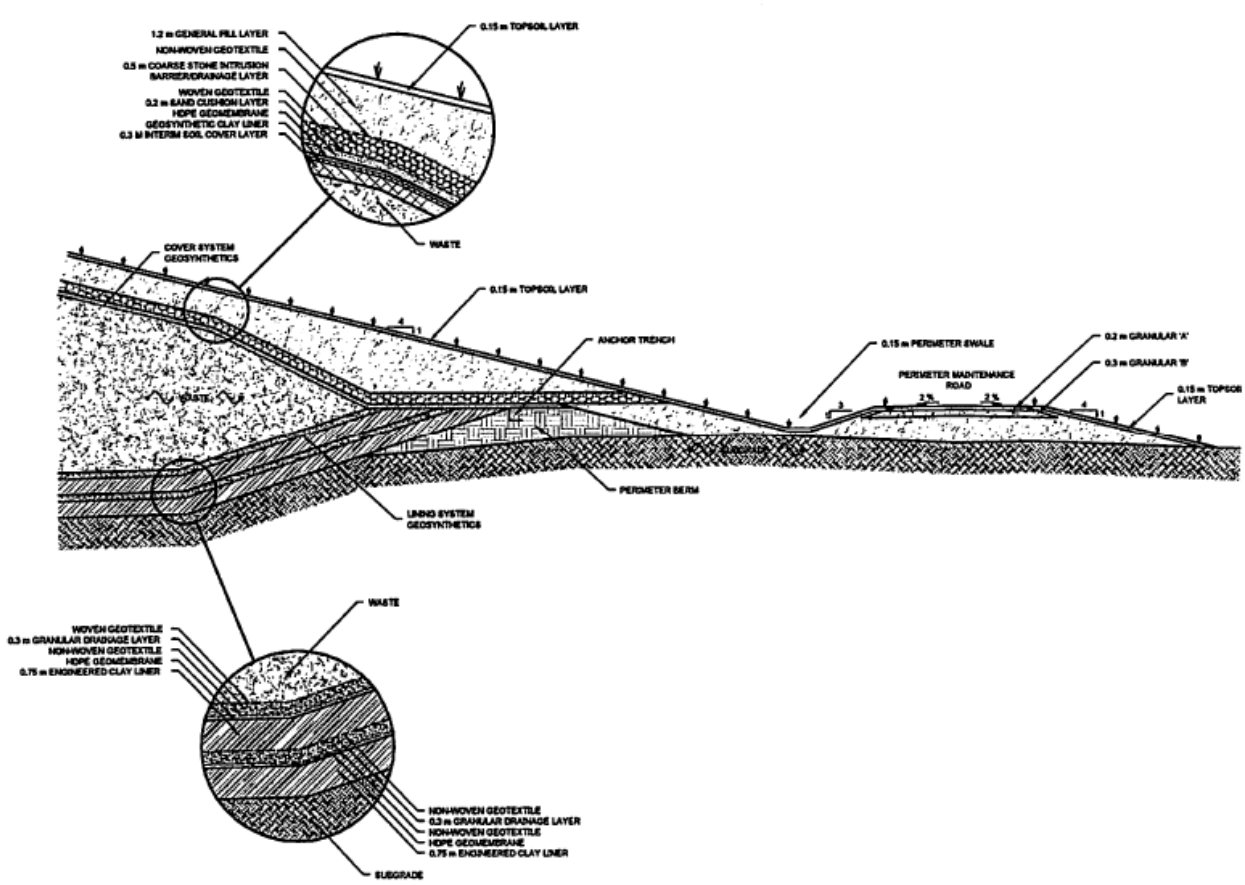

Figure 1: Typical Section of the Port Hope Long-Term Waste Management Facility [10]

Typical concentrations of Ra-226 and Th-230[1] in the waste are 0.3 Bq/g and 3.4 Bq/g respectively for 'marginally contaminated' soil and 310 Bq/g and 817 Bq/g respectively for the remaining waste.

The Port Hope Long-Term Low-Level Radioactive Waste Management Project is a CNSC licensed process and as such required detailed design, long-term safety analysis and environmental assessment to show compliance with all relevant laws, regulations and standards, and public consultation.

2. MANAGING RADIOACTIVE WASTE IN THE CANADIAN NON-NUCLEAR INDUSTRIES

In accordance with the CNSC General Nuclear Safety and Control Regulations [2];

> "*Naturally occurring nuclear substances, other than those that are or have been associated with the development, production or use of nuclear energy, are exempt from the application of all provisions of the Act* [1] *and the regulations made under the Act except the following:*

[1] Ra-226 and Th-230 are daughter products in the U-238 decay chain.

(a) in the case of a nuclear substance having a specific activity greater than 70 kBq/kg, the provisions that govern the transport of nuclear substances;

(b) *in the case of a nuclear substance listed in the schedule to the* Nuclear Non-proliferation Import and Export Control Regulations [11]*, the provisions that govern the import and export of nuclear substances.*"

Although naturally occurring radioactive materials (NORM) have always been present in various concentrations in the environment and in the tissues of every living animal, including humans, the hazards of similar quantities of NORM radionuclides are identical to those of the same radionuclides from regulated industries. The concentration of NORM in most natural substances is so low that the associated risk is generally regarded as negligible, however higher concentrations may arise as the result of industrial operations such as:

- oil and gas production
- mineral extraction and processing (e.g. phosphate fertilizer production)
- metal recycling
- thermal electric power generation
- water treatment facilities

As NORM is not regulated by the CNSC, NORM-related activities fall under the jurisdiction of the provinces and territories. This has lead to inconsistent application of radiation protection standards with numerous agencies involved as materials cross jurisdictional boundaries. Health Canada has published the *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)* [12], hereafter referred to as the *Guidelines*. The *Guidelines* were developed and issued in 2000 by the NORM Working Group, a working group of the Federal Provincial Territorial Radiation Protection Committee. This group represents the interests of provincial and territorial regulators and includes affected industries in the petroleum production, fertilizer manufacturing and metal re cycling industry sectors. The group was supported by Health Canada and the CNSC.

The basic principle of the *Guidelines* is that persons exposed to NORM should be subject to the same radiation exposure standards that apply to persons exposed to CNSC-regulated radioactive materials. No distinction is made regarding the origin of the radiation, whether it is NORM in its natural state or NORM whose concentration of radioactive material has been increased by processing (Technologically Enhanced NORM or TENORM). However, because of the ubiquitous nature of NORM, in dealing with situations where natural radiation is significant the cost of any intervention must be taken into account in accordance with the As Low As Reasonably Achievable (ALARA) principle.

With respect to managing NORM contaminated waste, the *Guidelines* recommend that NORM may be released with no radiological restrictions if it will not result in a dose to an individual greater than 0.3 mSv in a year in its final disposition. Derived Release Limits for the amount and concentration of NORM materials that should meet this criterion are specified in the *Guidelines* (referred to as Unconditional Derived Release Limits (UDRLs)). NORM quantities in excess of the UDRLs may, after a specific site review, be released without further consideration if it can be confidently shown to meet the 0.3 mSv dose criterion. Guidance on disposal of NORM waste that cannot be released without radiological restrictions is not provided in the *Guidelines*.

Two case studies of NORM waste management projects are presented below.

2.1 Large NORM-contaminated Slag Pile in Ontario

An aluminothermic process in the production of ferrocolumbium from Brazilian and Canadian pyrochlore ores carried out between 1969 and 1981 at a site in Ontario resulted in the generation of slag contaminated with NORM. Approximately 9,500 m^3 of co-mingled and potentially radioactively contaminated slag was stockpiled outdoors on the site (Figure 2).

Figure 2: View of NORM-contaminated Slag Pile

A Provincial Order was issued by the Ontario Ministry of the Environment in 2004 requiring the site owner to conduct radiological characterisation of the pile and to provide recommendations for disposal or management on-site in accordance with the *Guidelines*.

The characterisation had several interesting challenges; for example one side of the pile had a very steep slope (Figure 3) and, due to the schedule requirements of the Provincial Order, borehole sampling was conducted in temperatures as low as -43^{o}C (Figure 4).

Figure 3: Surface Sampling from Steep Pile Face

Figure 4: Borehole Sampling of Slag Pile

The radiological analyses showed that the slag consists of an inhomogeneous distribution of NORM contaminated material with total specific activities in sampled slag of U-238, Th-232 and daughter products ranging from minimal detectable activities to over 400 Bq/g. Approximately 3,700 m^3 of the pile material had measured activities in excess of the *Guidelines* UDRLs and hence could not be disposed of without radiological restrictions.

A site was found in the USA that could accept the waste up to concentrations of up to 74 Bq/g. However, due to the financial costs and the fact that some of the waste was higher than the site's Waste Acceptance Criteria (WAC), this disposal option was not deemed feasible.

A pathways analysis was conducted to determine whether the pile material with concentrations greater than the UDRLs could be disposed of in a manner such that it could be confidently shown that it would not result in a dose to an individual greater than 0.3 mSv. This analysis concluded that if the waste could be buried under one metre of clean soil at a landfill site that had restrictions on future human intrusion (e.g. a hazardous/special waste landfill site), the dose criterion could be met.

Notwithstanding the findings of the pathways analysis, a landfill site willing to accept the waste was not found. The slag pile remains stored outdoors on the site at the time of writing.

2.2 Re-use of NORM Contaminated Land in Newfoundland

Historical operations on the site involved the extraction of nickel from ores containing NORM. The resulting slag with elevated concentrations of NORM was crushed and used as in-fill in a wharf area on the site. A remedial action/risk management plan was required for the remediation of the area for use as a laydown area for shipping and receiving of marine bulk cargo and containers.

There were no Provincial Orders associated with the area or the work. A radiological characterization was conducted of the site. The concentrations of the radionuclides in the U-238 decay series in the samples taken were higher than the UDRL of 0.3 Bq/g. Therefore, this material could not be disposed of without radiological restrictions unless it can be shown that the waste, in its final disposition, will not contribute a dose to an individual that is greater than 0.3 mSv per year.

A dose assessment was conducted to determine potential occupational doses to workers in the area based on projected occupancies. It was found that annual doses may reach 0.61 mSv. This is less than the CNSC regulatory dose limit of 1mSv per year for persons who are not Nuclear Energy Workers, but greater than the dose constraint of 0.3 mSv per year suggested by the *Guidelines*.

The site owners did not want to attempt to dispose of the NORM contaminated material. Hence it was recommended that the area be covered in clean topsoil to provide radiological shielding and minimise internal exposures. The topsoil was recommended to be capped (for example with tarmac) to prevent erosion which may hinder the effectiveness of the topsoil in reducing the potential doses over time.

Potential doses were also assessed for workers involved in the construction / infrastructure work required for preparation of the area. These doses were all assessed to be below the 0.3 mSv dose constraint.

The site also has a NORM-contaminated slag pile of volume greater than one hundred times the size of the slag pile discussed in Section 2.1. There are currently no plans to manage this waste.

3. SUMMARY

There are significant differences in the regulatory oversight for radioactively contaminated materials in the nuclear and non-nuclear industries. Naturally Occurring Radioactive Materials at non-nuclear facilities are not subject to regulation by the Federal nuclear regulatory body. In many provinces, there are no regulations governing management of such materials. The unconditional clearance levels for NORM waste in the Health Canada guidelines are derived on the basis of a 0.3 mSv annual dose to members of the public. However in most provinces there

is no general process enforcing the application of these guidelines and there is no practical oversight provided by either federal or provincial regulators.

In the nuclear industry, the management of radioactively contaminated materials is regulated and enforced by the CNSC. The NSRDR unconditional clearance criteria [4] are based on a 10 μSv annual dose criterion and provide a straightforward path for disposal. However provincial regulations may cause impediments to disposal of cleared material. For example Ontario regulations would not prohibit cleared materials from going to a landfill in general; however a specific landfill's license or certificate of approval may have restrictions on radioactivity which are inconsistent with CNSC clearance levels.

4. REFERENCES

1. CNSC Nuclear Safety and Control Act, N-28.3, 1997.
2. CNSC General Nuclear Safety and Control Regulations, SOR/2000-202, 2000.
3. CNSC Nuclear Security Regulations, SOR/2000-209, 2000.
4. CNSC Nuclear Substances and Radiation Devices Regulations, SOR/2000-207, 2000.
5. CNSC Class I Nuclear Facilities Regulations, SOR/2000-204, 2000.
6. CNSC Packaging and Transport of Nuclear Substances Regulations, SOR/2000-208, 2000.
7. CNSC Regulatory Policy P-290 – Managing Radioactive Waste, 2004.
8. CNSC Regulatory Guide G–320 - Assessing the Long Term Safety of Radioactive Waste Management, 2006.
9. Canadian Standards Association (CSA) N292.3-08 - Management of Low- and Intermediate-Level Radioactive Waste, 2008.
10. Natural Resources Canada, Screening Report – The Port Hope Long-Term Low-Level Radioactive Waste Management Project, 2006.
11. CNSC Nuclear Non-proliferation Import and Export Control Regulations, SOR/2000-210, 2000
12. Health Canada has published the Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM), 2000.