

ENVIRONMENTAL ASSESSMENT REGISTRATION

NORM Contaminated Equipment Storage and Decontamination Facility

SUBMITTED TO:

**NEWFOUNDLAND AND LABRADOR MINISTER OF THE DEPARTMENT ENVIRONMENT AND CLIMATE
CHANGE**

PO BOX 8700

ST. JOHN'S, NL, A1B 4J6

ATTENTION: DIRECTOR OF ENVIRONMENTAL ASSESSMENT

PREPARED BY:

PARDY'S WASTE MANAGEMENT AND INDUSTRIAL SERVICES LIMITED

30 KYLE AVENUE

MOUNT PEARL, NL A1N 4R5





NAME OF UNDERTAKING: NORM Contaminated Equipment Storage and Decontamination Facility

PROPONENT:

- (i) Name of Corporate Body: Pardy's Waste Management and Industrial Services Limited
- (ii) Address: 30 Kyle Avenue, Mount Pearl, NL, A1N 4R5
- (iii) Chief Executive Officer:
 - a. Mr. Derek Pardy
 - b. President
 - c. 25 Stentafor Avenue, Pasadena, NL, A0L 1K0
 - d. (709) 686-2013, (709) 632-4672

- (iv) Principal Contact Person for purposes of environmental assessment:
 - a. Steve Moores
 - b. General Manager & Director
 - c. 30 Kyle Avenue, Mount Pearl, NL, A0L1K0
 - d. (709) 368-4350, (709) 632-1767

THE UNDERTAKING:

- (i) Name of the undertaking: NORM Contaminated Equipment Storage and Decontamination Facility
- (ii) Purpose of the undertaking: For Pardy's Waste Management and Industrial Services Limited to use existing infrastructure and property to develop a facility to store NORM contaminated equipment, for the purpose of off-island transport and disposal, and to clean NORM contaminated re-useable equipment to extend equipment life cycle.



DESCRIPTION OF THE UNDERTAKING:

Pardy's Waste Management and Industrial Services Limited currently provides waste management and industrial cleaning services in Newfoundland and Labrador. A key area of focus since the 1990's has been the oil and gas industry. Pardy's has been a reliable service provider since the commencement of the Hibernia construction project and has learned to evolve with the industry to provide waste management solutions when required. Due to the anticipated NORM waste generation and lack of facilities permitted in Newfoundland and Labrador to decontaminate NORM contaminated equipment Pardy's is prepared to proceed with this undertaking to provide a solution for the waste to our existing and potential customers.

NORM is material found where radioactive elements occur in the environment. Norm primarily consists of uranium and thorium as well as other elements that also release radium and radon gas once they begin to decay when exposed to the surface as a result of human activity. NORM may be referred to as Technically Enhanced Naturally Occurring Radioactive Materials (TENORM). The NORM radionuclides of usual concern associated with the petroleum industry include: Radium 226 and 228, and Lead 210. Examples of NORM waste associated with petroleum production are produced sands, wastewater and contaminated equipment.

The processing of raw materials by many resource-based industries may increase the concentration of radioactive substances in and around infrastructure, pipes (scale), drilling equipment and storage tanks. Special precautions are required during the handling, storage, transportation, decontamination and disposal. Improper controls of NORM can lead to the spread of NORM contamination, and result in contamination of land and groundwater, resulting in potential exposure to workers, the public and the environment.

*Norm Contaminated: means waste that exceeds the public exposure levels but do not exceed the levels at which they are classified as radioactive. **Department of Environment and Climate Change, Municipal Affairs and Environment, GD-PPD-079.1, December 2017.***

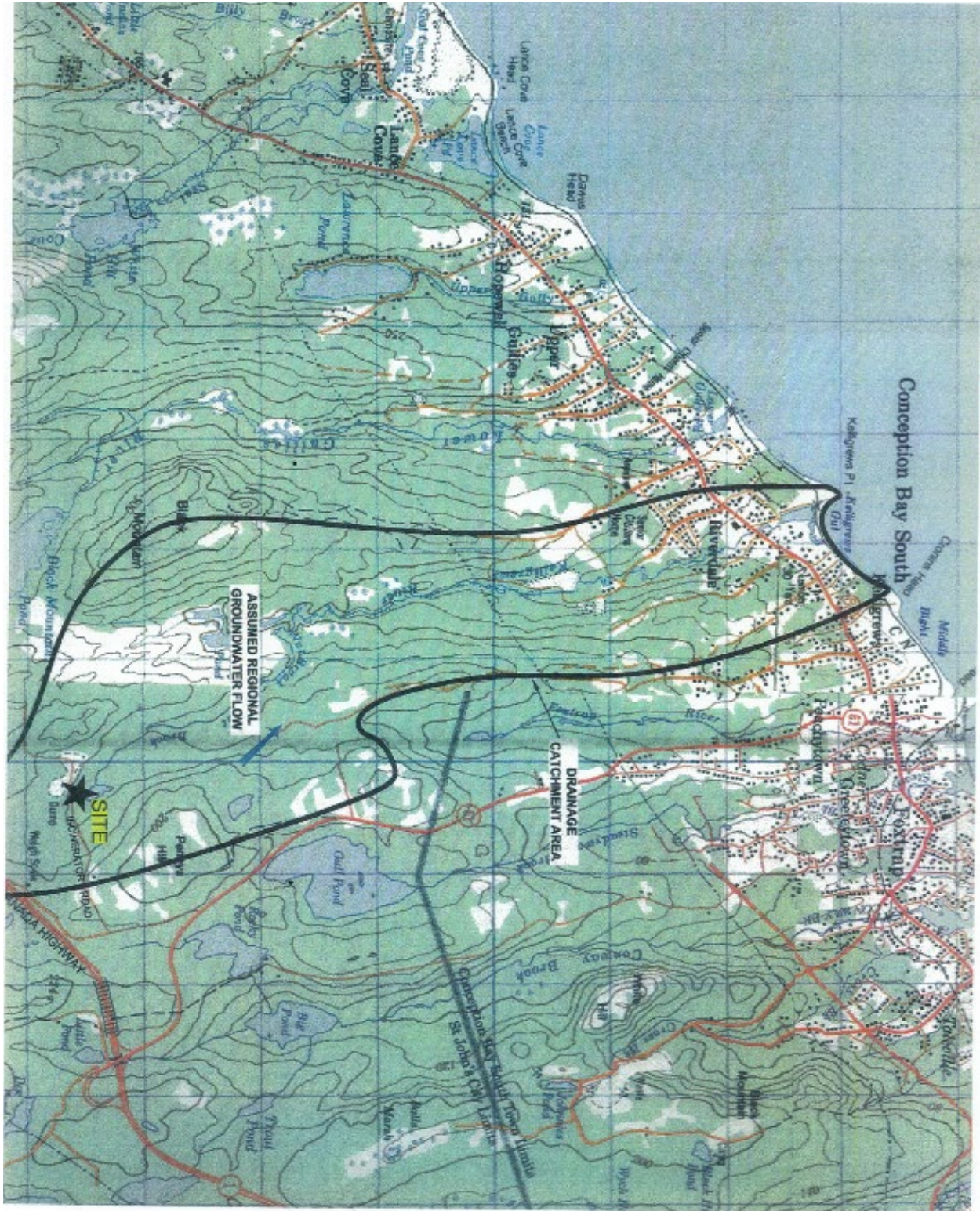
Pardy's is proposing to develop a NORM Contaminated Equipment Storage and Decontamination Facility at their existing 267 Incinerator Road location. This facility will provide a local solution for the management, storage and decontamination of NORM contaminated equipment according to Guidance Document GD-PPD-079.1, Norm Waste Management, December 22, 2017. (Attached)

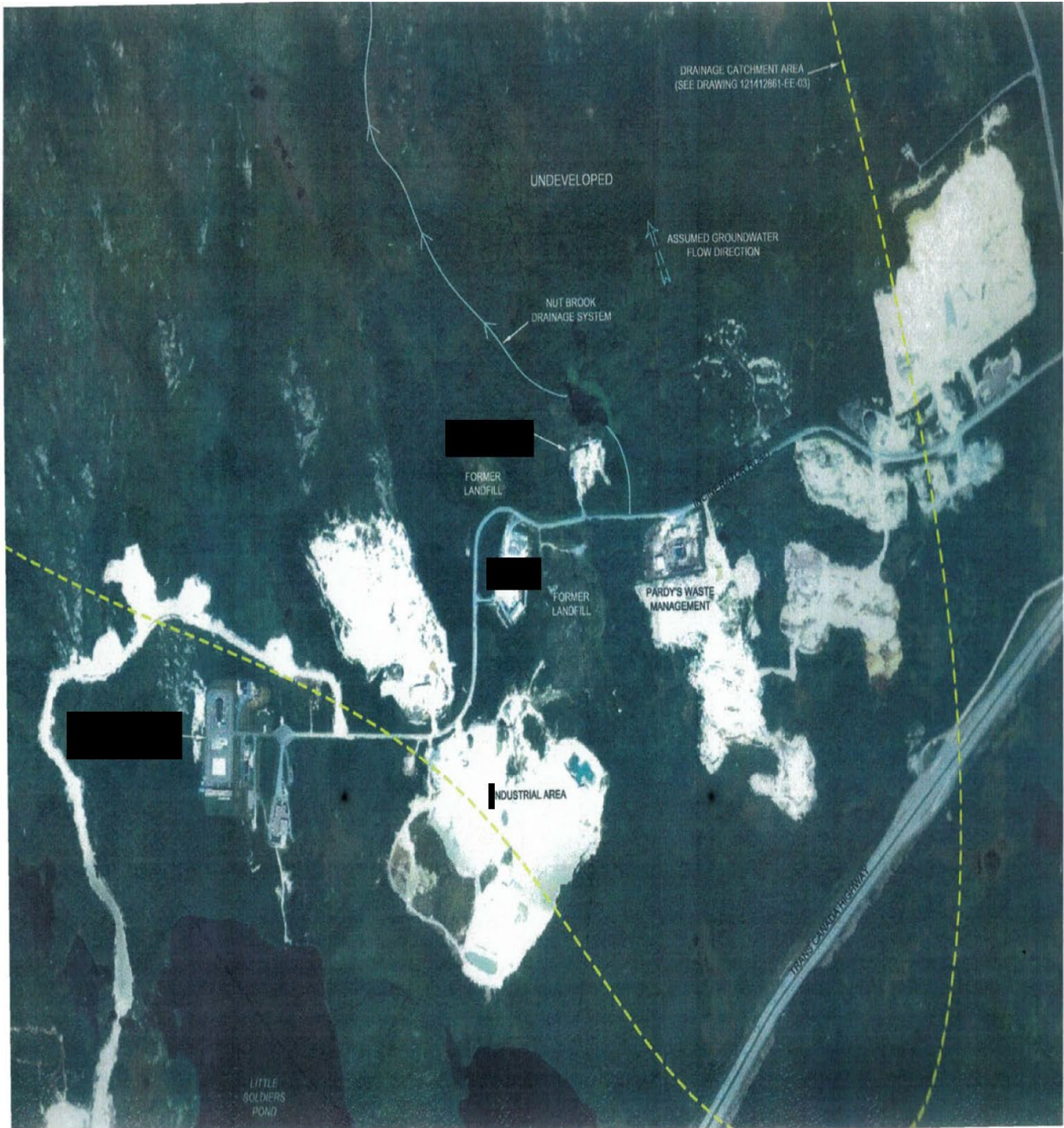
There will be no treatment or disposal of NORM waste at the proposed facility. Norms will be managed for trans shipment to an approved final disposal location located in Western Canada.

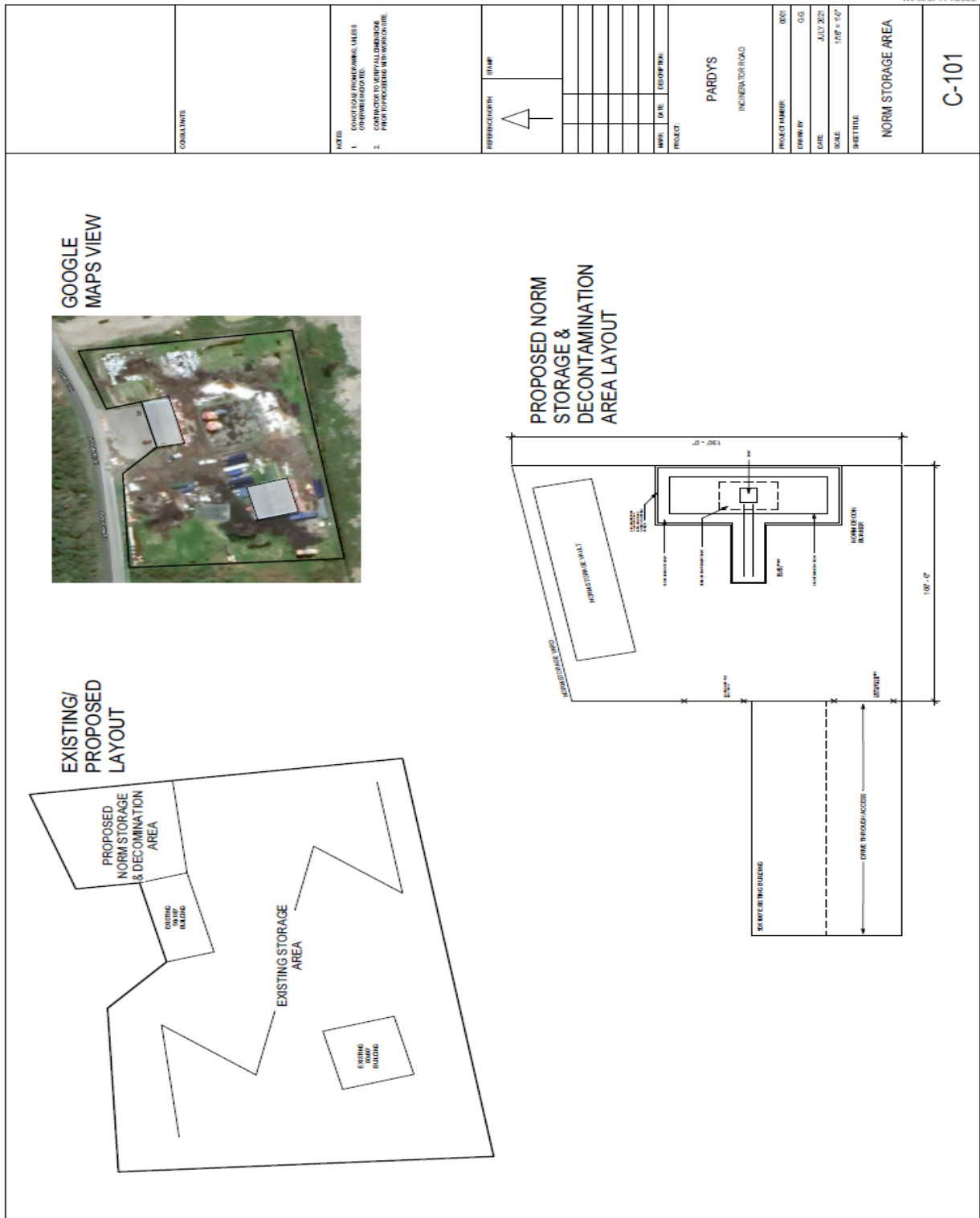


The undertaking involves using previously developed land on Pardy's owned property to create a 100' x 130' secure storage area with restricted access which will contain a storage vault and decontamination chamber as specified in GD-PPD-079.1.

- (i) Geographic Location – The proposed site location and existing infrastructure located at 267 Incinerator Road, Foxtrap, NL. The zoning of the site is General Industrial. Location map can be found below. The site is flat with no predominant slope. Anticipated groundwater flow direction is to the north. Bedrock in the area of the site consists of granite of the Late Proterozoic to Cambrian era. The subject site is 1.8 hectares and surrounded by a secure chain-link fence with restricted access. There are currently two building on the property that were constructed approximately 20 years ago. The current undertaking is proposed for the north-east corner of the subject property that is currently used for equipment storage and not associated with the other activities on the property.



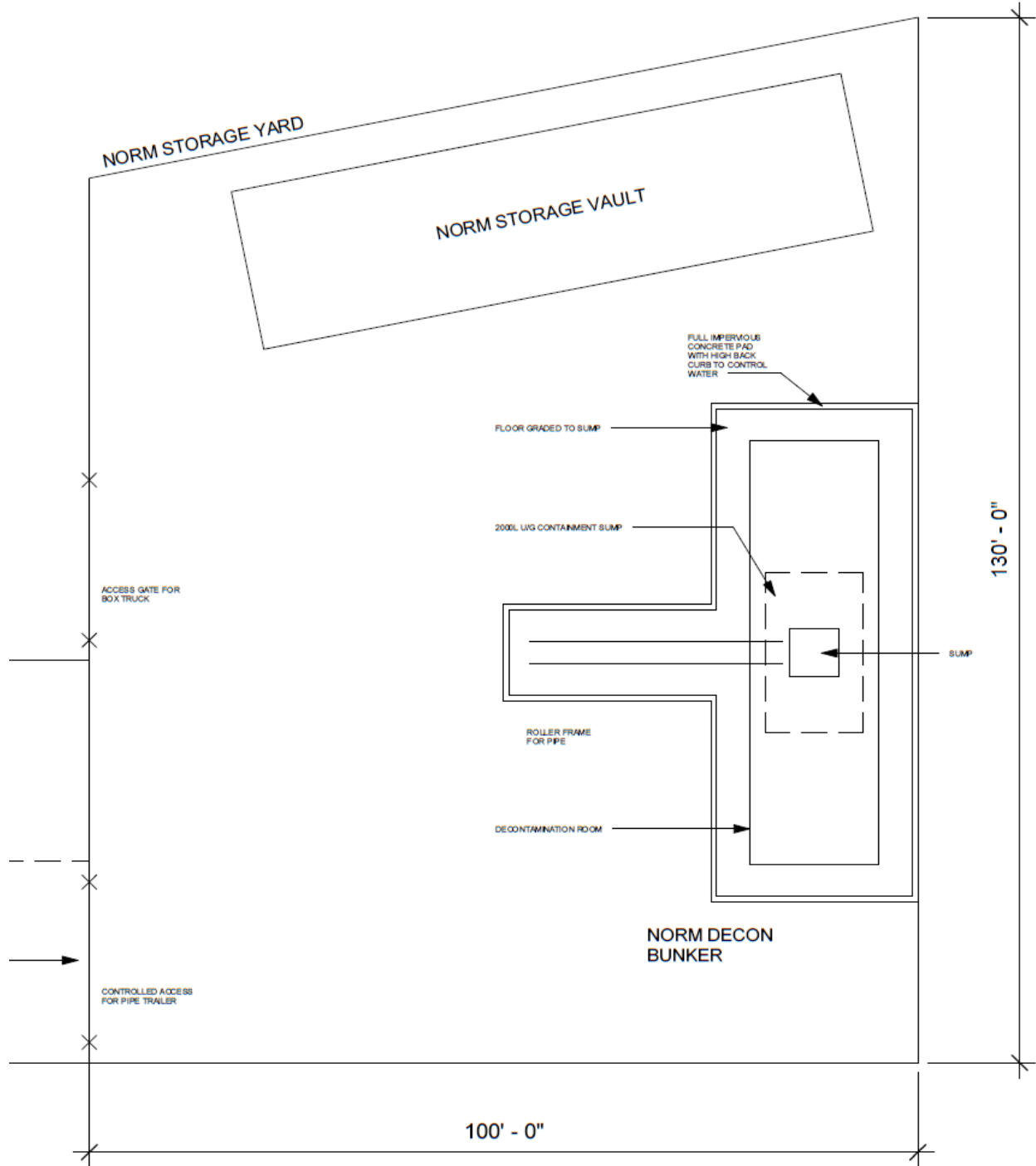




- (ii) Physical Features – The proposed undertaking includes three major installments. A Limited access compound will be created by erecting a chain-link fence with limited access control points inside the existing perimeter fence on the property. The undertaking will occupy an area of 13,000 square feet. The NORM Storage Vault will be developed using a steel container with rear and side loading doors. The floor of the container will be Steel and laid on a concrete pad. No utilities will be connected to the Storage Vault. The NORM Decontamination Chamber will be developed using a similar steel container with rear and side doors. The decontamination chamber will be underlain by a reinforced concrete pad sloped into a containment sump. The containment sump will be self contained using a double wall underground storage tank. A dedicated pump will be used to transfer washings to approved containers for final disposal. Other features as required by the most recent version of GD-PPD-079.1 will be incorporated to the final design to ensure the facility meets all permit and regulatory requirements for safe operation.

A conceptual preliminary design can be found below. As this property is currently occupied, and the undertaking will not produce any emissions or effluent no adverse impacts to topography, water bodies, vegetation, wildlife, fish or any other receptors is anticipated.

The subject site and all neighbouring properties are zoned Industrial General. Dewatering Technologies (Formerly Rothsay Rendering) is located to the north. Clarkes Excavation is located to the south. The former CBS landfill is located to the west followed by Terra Pure where an existing NORM storage facility is located. Capital Ready Mix is located to the north east. A Newfoundland and Labrador Department of Transportation and Works depot is located to the east. Recreationally zoned land is approximately 400 meters to the north of the subject site, however, does not appear to be used frequently by the public. The nearest residential dwelling to the site is approximately 3,000 meters to the north east.



- (iii) Construction – Construction activities associated with the undertaking are minimal. A chain link fence and controlled access points need to be installed. An underground storage tank, sump and associated pad are required for the decontamination chamber, and a concrete pad is required for the storage vault. All other containers and equipment are modular and require assembly. The construction period is expected to take approximately 3 months following acquisition of all necessary approvals. The desired date to commence construction is April or May of 2022. No potential sources of pollution are anticipated during construction. As the undertaken is being proposed for an already developed and occupied property, no resource conflicts have been identified.



- (iv) Operation – This undertaking is limited to the decontamination of NORM contaminated equipment and the temporary storage (less than 1 year from date of reception) of NORM waste requiring disposal at an approved site. This undertaking does not include the assessment or confirmation of NORM's beyond what is routinely required by the original owners of equipment or waste contaminated with NORM's. The intent of the undertaking is to continue to provide waste management solutions to Newfoundland and Labrador where demand exists. As such the facility will be operated in accordance with requirements of permits and certificates of approval issued pursuant to the latest version of GD-PPD-079.1, and The Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials. Prior to operation of the facility a NORM management plan including a NORM health and safety program, waste management program and emergency response plan will be developed to ensure safe and responsible operation of the facility.

Pardy's Waste Management and Industrial Services Limited will work with customers to clearly understand the quantities and concentrations of NORM's requiring management. Careful planning will take place based on guidance documents to ensure the on-site volumes of NORM do not exceed regulatory guidelines.

All NORM impacted equipment and waste will be manifested from the point of origin and accompanied by owner NORM survey documents to ensure the concept of "cradle to grave" waste management is followed. All NORM impacted equipment and waste will be stored in the designated vaults until transfer to final disposal occurs.

Regular surveys of the NORM Storage and Decontamination facility will occur to ensure regulatory requirements are adhered to.

Decontamination of NORM impacted equipment will follow GD-PPD-079.1 and requirements of certificates of approval issued for NORM Decontamination.

The only waste generated in this facility will be wash water / scale / sludge from the decontamination sump. This waste will be containerized for shipping off-island to an approved facility. As all decontamination will occur in an isolated contained steel vault, no air emissions, effluent or solid waste will be released.

Due to the design of the NORM Storage and Decontamination Facility, spills or releases from the site are not anticipated. Pardy's Waste Management and Industrial Services Limited are trained first responders to environmental emergencies and have been for over 30 years.



Following the development of a NORM management plan, additional training will be provided to operators handling NORM in conjunction with our Leader of Corporate Safety and Wellness and trained Radiation Safety Officers. Every person handling or supervising Management of NORMS will receive approved NORM Awareness training.

Although the requirements of GD-PPD-079.1 are comprehensive and very stringent Parady's will adhere to the general rules below to ensure safe environmental practices are followed:

- Mandatory review of all survey documentation prior to agreement to receive equipment or waste at Parady's;
- Notification to the jurisdictional authorities (Waste Management Section, Pollution Prevention Division) prior to the movement of any NORM's from original owner to Parady's;
- Mandatory load inspections prior to shipment of NORMS from original owner to Parady's;
- Specific receiving documents completed at time of reception for storage at Parady's;
- Notification to the jurisdictional authority prior to decontamination activities, which may include decontamination and waste management plan prior to commencement;
- Use of appropriate means of containment for equipment and waste;
- Parady's will reserve the right to refuse any unidentified waste or equipment that was not declared prior to the commencement of activities and that poses a risk to the safe operation of the facility and protection of human health.

Parady's Waste Management and Industrial Services Limited will follow all necessary reporting structure required to notify interested parties on a regular basis.

No resource conflicts exist with the operation of this undertaking.



(v) Occupations – Pardy's currently employs adequate resources to undertake Norm Storage and Decontamination. Current occupations include the following:

- Manager of Waste Operations;
- Field / lab chemist (NOC2112);
- RSO (NOC2112)
- Decontamination Process Operators (NOC 9212);
- Labourers;

These are full time positions with Pardy's and it is anticipated that the undertaking will require addition of staff that will be trained and on-the-job trained to operate equipment related to the NORM impacted equipment decontamination process.

Pardy's has supported and will continue to recruit graduates from the College of the North Atlantic Process Operations Engineering Technology (POET) program, as they possess the theoretical knowledge and applied science background to effectively operate equipment required to manage the mud slops waste stream.

Pardy's is an equal opportunity employer and is an equal opportunity employer. As an executive member to the International Union of Operating Engineers, Local 904, one of our operations staff Katlyn Hutchings also advocates for the placement of Women from the Local 904 with Pardy's. Pardy's maintains active inclusion, respectful workplace, workplace violence/harassment policies to ensure that all employees and potential employees have a fair, open and supportive workplace that encourages meaningful career employment based on skill and ability without any bias.

(vi) Project Related Documents

- Newfoundland and Labrador Department of Environment and Climate Change, Municipal Affairs and Environment, Guidance Document, GD-PPD-079.1, December 22, 2017;
- Health Canada, Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM), October 2000;



APPROVAL OF THE UNDERTAKING

Pardy's Waste Management and Industrial Services Limited currently has an established working relationship with the Newfoundland and Labrador Department of Environment and Climate Change, Pollution Prevention Division – Waste Management Section. This undertaking will require a certificate of approval to operate a waste management system pursuant to the Environmental Protection Act. This undertaking will also require relevant development permits from the City of St. John's.

SCHEDULE

Pardy's Waste Management and Industrial Services Limited would like to commence this undertaking as soon as possible. Document preparation, training and design work can commence immediately upon approval of the undertaking and construction activities can commence during the 2022 construction season.

FUNDING

The undertaking does not require any funding or financing to commence. All costs to operate the system, facility and transportation network will be funded by Pardy's. No grants or funds from a government agency are required.

CLOSURE

Pardy's Waste Management and Industrial Services Limited have been managing waste in NL for more than 30 years. We believe in developing sustainable solutions for residents and industry throughout Newfoundland and Labrador. Pardy's believes in responsible waste management and developing opportunities to ensure that work and employment remain in Newfoundland and Labrador. Pardy's believes in building relationships with customers, suppliers and regulators alike to support the growth of the energy sector and all industry. We humbly request your support in our undertaking.

Respectfully Submitted,

A handwritten signature in black ink, appearing to read "Steve Moores", is written over a white background.

Steve Moores,

General Manager and Director



Guidance Document

Title: NORM Waste Management

Prepared By: Joan Hann

Issue Date: December 22, 2017

Amended:

Approved By:


Dan Michielsen, Director

GD-PPD-079.1

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SUBJECT

The management of Natural Occurring Radioactive Material (NORM).

OBJECTIVE

To explain measures implemented to provide adequate protection to human health and the environment during handling and temporary storage of NORM waste and of equipment that requires NORM decontamination.

BACKGROUND

NORM is material found where radioactive elements occur in the environment. NORM primarily consists of uranium and thorium as well as other elements that also release radium and radon gas once they begin to decay when exposed to the surface as a result of human activity. NORM may be referred to as Technically Enhanced Naturally Occurring Radioactive Materials (TENORM). The NORM radionuclides of usual concern associated with the petroleum industry include: Radium 226 and 228, and Lead 210. Examples of NORM waste associated with petroleum production are produced sands, wastewater and contaminated equipment.

The processing of raw materials by many resource-based industries may increase the concentration of radioactive substances in and around infrastructure, pipes (scale), drilling equipment and storage tanks. Special precautions are required during the handling, storage, transportation, decontamination and disposal. Improper controls of NORM can lead to the spread of NORM contamination, and result in contamination of land and groundwater, resulting in potential exposure to workers, the public and the environment.

DEFINITIONS

Activity: (becquerel or Bq) solely indicates the number of nuclear disintegrations per second but is also encountered as derived units such as activity per mass or volume (Bq/g[solid], Bq/L[liquid] and Bq/Nm³ [gas]).

Alpha (α): Positively charged particles consisting of two protons and two neutrons that are emitted by the nuclei of radioactive (unstable) elements as they decay. Alpha particles are relatively large and can be stopped by skin or a sheet of paper. An alpha particle is a helium nucleus. (*particules alpha*).

Beta (β): High-energy negatively charged electrons or positively charged positrons that are ejected by radioactive (unstable) elements as they decay. A beta particle is identical in mass and charge to an electron. Beta particles are relatively small and can be stopped by a sheet of aluminum or plastic a few millimetres thick. (*particules bêta*).

Effective dose: A measure of dose designed to reflect the amount of radiation detriment. The effective dose is obtained by multiplying the equivalent dose of each tissue or organ by an appropriate tissue weighting factor and summing the products. The unit of measurement is the sievert (Sv). (*dose efficace*).

Gamma (γ): Penetrating electromagnetic radiation emitted by an atomic nucleus during radioactive decay; a wave form of ionizing radiation. Also called gamma radiation. (*rayonnement gamma, rayons gamma*).

NORM Contaminated: means waste that exceeds the public exposure levels but do not exceed the levels at which they are classified as radioactive.

Radiation: Energy travelling through space in the form of waves or particles. Ionizing radiation (e.g. alpha particles, beta particles, gamma rays, X-rays and neutrons) has the ability to remove electrons from the matter it encounters.

Radioactive: Exhibiting radioactivity; emitting or relating to the emission of ionizing radiation or particles such as alpha and beta particles, neutrons or gamma rays. (*radioactif, radioactive*)

Radiation dose: A quantity of radiation that one is exposed to and a measure of the amount of energy absorbed by the body and is measured in units called the Sievert (Sv). Higher number of Sv equals higher dose equals higher risk of energy.

LEGISLATION

The legislative authority for the management of Waste Dangerous Goods/Hazardous Waste including NORM Waste is provided through the *Environmental Protection Act*, Parts VIII and XI (specifically sections 30, 31, 78 and 83). The following non-exhaustive list of legislation also applies to waste management facilities/ systems and sites:

Provincial Legislation

- *Environmental Protection Act* and Regulations
- *Occupational Health and Safety Act* and Regulations
- *Environmental Control Water and Sewage Regulations under the Water Resources Act*

- Accredited Policy (PD;PP2001-01.2)

Federal Legislation and Guidelines

- Health Canada – Canadian Guidelines for the Management of Natural Occurring Radioactive Material (NORM)
- *Transportation and Works Act* and Regulations
- Canadian Nuclear Safety Commission

ENVIRONMENTAL ASSESSMENT AND APPROVAL PROCESS

Storage and decontamination facilities for NORM waste may require registration under the *Environment Assessment Regulations*. Industries planning to handle or store NORM waste shall contact the Environmental Assessment Division of Environment and Climate Change. Once released from the Environmental Assessment process, a request for a Certificate of Approval to construct and operate a NORM waste management facility is required pursuant to the *Environmental Protection Act*, Part XI. Prior to issuing an approval prerequisite information shall be submitted for review (**refer to Appendix A**).

DETECTION

Radioactive materials are unstable atoms that release radiation (in the form of alpha, beta and gamma) during decay process over time. The activity of NORM is measured by concentration (Becquerel - Bq/g or Bq/l). The larger the activity the more radiation produced by the source.

Radioactive contamination involves both internal and external exposures from contact with a radioactive material that may be encountered on surface or equipment. Prior to conducting any activity related to NORM, consultation with the Department of Service NL (Occupational Health and Safety) is required. **APPENDIX B** provides an overview on worker safety practices.

Generators/facility operators are responsible for conducting initial reviews of all NORM-contaminated sources prior to material arriving at approved Waste Dangerous Goods /Hazardous Waste storage facilities. NORM screening surveys are necessary to identify the potential exposure of workers to NORM; and for detecting radiation on equipment and surrounding environment. Surveys shall be conducted by personnel trained in radiation safety to determine if the suspect material is NORM. Radiation readings above typical background radiation levels may indicate the presence of NORM. The first step involved in the survey is to start with natural background reading at the worksite which is taken away from the source of radiation. This number should be subtracted from actual reading at NORM source to determine true value. (**Table 1, provides a summary of information to be included in a survey form**).

Table 1: Items to be included in NORM Survey Form

- Name of generator/client
- Date of survey completed
- Staff completing survey
- Type of equipment (location) being surveyed
- Type of instruments being used
- Natural background reading in $\mu\text{Sv/hr}$ & Counts Per Minute (CPM)
- Dose reading at source and 0.5 meters from source in (both in $\mu\text{Sv/hr}$)
- Surface contamination reading at source and 0.5 meters from source in (CPM)

NORM surveys are conducted with specialized instruments for: the detection of immediate dose (dose rate); and total/accumulated dose; and to measure contamination/presence of surface radioactivity (*Table 2 summarizes surveys, instruments and use*).

Table 2: Types of Surveys and Instruments

<i>Type of Survey</i>	<i>Use</i>	<i>Instrument</i>
Screening	Used to identify NORM exposures during initial screening and is used as a survey meter and for dose rates.	Geiger Counter (Operates in a variety of environments and is inexpensive Scintillation (more efficient for gamma radiation and detects low radiation)
Radiation	Used for worker assessment protection for dose rates based upon results from screening survey.	Geiger Counter (Operates variety of environments and is inexpensive Scintillation (more efficient for gamma radiation and detects low radiation)
Contamination	Used to check surface contamination of workers in air , and equipment and tools (interior and exterior)	Pancake Monitor to detect radioactivity measure alpha and beta surface contamination measured in counts per minute (CPM) activity over an area

Note: All equipment shall be calibrated in accordance with manufacturer's specifications and batteries shall also be checked regularly

NORM STORAGE

Below are storage requirements for the temporary storage of NORM contaminated waste at approved storage facilities.

- The storage of NORM waste shall be in a separate designated area with access limited to authorized personnel.
- All containers and equipment shall be labeled and sealed.
- NORM waste shall be stored in CSA approved containers.
- The NORM storage area shall be in a trailer and/or a designated area within a building segregated from non-contaminated items and any other types of WDG/HW.

- The storage area shall be contained within a secured fenced area and properly identified with the wording as shown below:

CAUTION Naturally Occurring Radioactive Material - Authorized Personnel Only

- A liner shall be required beneath the storage area where liquid NORM wastes are being stored.
- Materials with higher radioactivity should be placed near the centre of the storage area.
- Large equipment shall be protected from exposure to the elements.
- Larger NORM contaminated equipment that cannot be stored within the trailer/building shall be sealed in 6ml plastic or equivalent above ground on designated racks and/or pallets.
- For equipment with contamination limited to interior surfaces, open ends shall be capped or sealed.
- Reasonable measures shall be taken to prevent radioactive material from becoming airborne.
- Minimizing operations that may generate dust containing NORM (e.g., cutting, grinding or polishing). Keep material wet and undisturbed.
- NORM waste is permitted for storage for up to 6 months (for NORM waste < 70 Bq/g); 90 days for radioactive waste > 70 Bq/g) from receipt, at which time all materials must be shipped off site to an authorized facility for treatment/disposal.

DECONTAMINATION

Fixed NORM contamination on equipment poses only an external NORM hazard and if the dose is low enough it is usually shielded by the type of containment and may be transported by a licensed transporter to an authorized facility for NORM decontamination. Removal of NORM contamination however, poses both external & internal risks as the material can become airborne very readily. Decontamination controls are required. The removal of scale during decontamination requires radiochemical analysis. The results shall meet Health Canada's, UDRL'S (Unconditional Derived Released Limits (UDRL's)) as set out in **Appendix C –Table 5.1, Diffuse NORM** prior to disposal in a non-hazardous waste stream. NORM sources with surface contamination (internal/external) less than the limits in **Appendix C – Table 5.3, Discrete NORM** can be released without further investigation to service companies (equipment to be refurbished) and/or scrap recyclers.

Decontamination of NORM equipment using mechanical/abrasive methods need to be conducted in a controlled manner to prevent spread of NORM contamination. Considerations to be followed include:

- If a hazard has been identified atmospheric monitoring may be required to meet (**Appendix C Table 5.1 – Diffuse NORM limits for air**).
- Where possible, decontamination systems should be automated, as it is significantly safer than decontamination associated with hand-jetting activities.

- A designated area for decontamination shall be totally enclosed within a concrete room/self-contained unit –automated (or equivalent) and include a segregated area for decontaminated equipment and containers for contaminated material.
- All filters shall be considered NORM contaminated waste at completion of work.
- Wetting down of tools/equipment to minimize the release of airborne particles is an OHS requirement.
- Process water used in this operation shall be collected in a separate closed unit and filtered and reused. Waste liquid collected shall not be connected to any external drainage.
- Scale material shall be collected in containers and samples collected and analyzed to determine radioactivity and determination of correct disposal method.
- All equipment and surfaces shall be inspected and monitored before and after decontamination and information documented. All equipment must be free of detectable radioactive contamination.
- Once the work area has been verified free of loose NORM contamination regular activities can be resumed.

TRANSPORTATION AND DISPOSAL

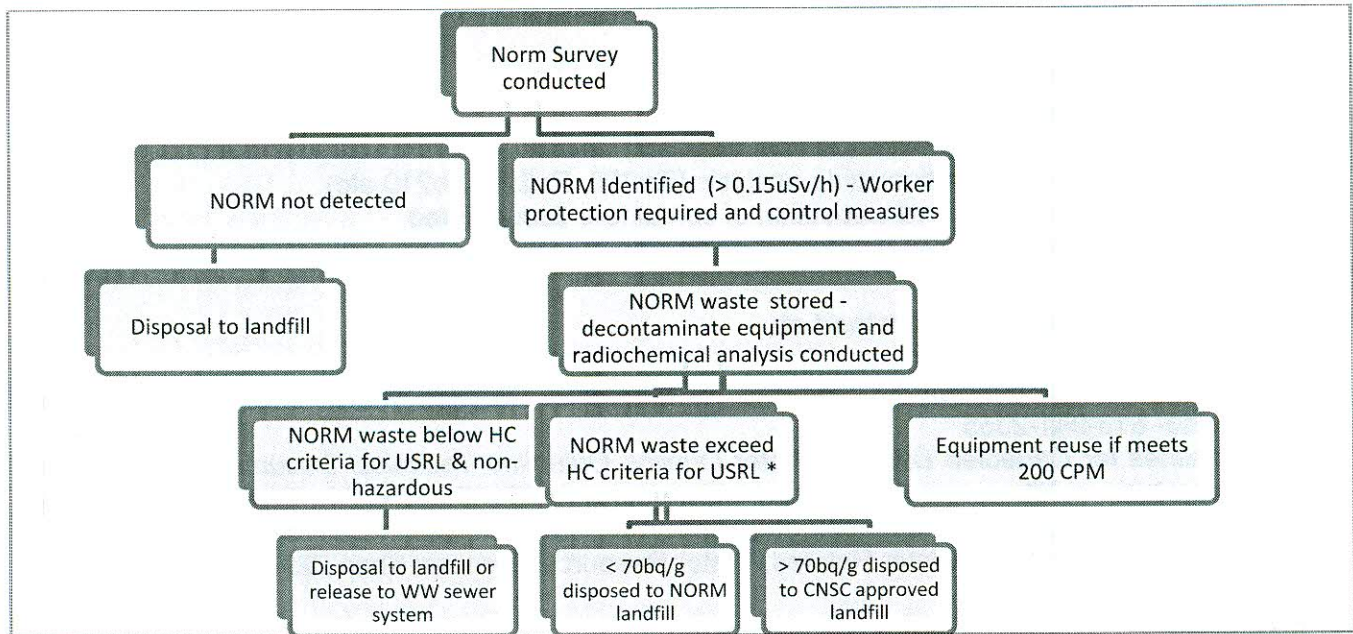
Facility operators shall ensure representative sampling and approved analytical methods are used for radiochemical analysis of NORM waste (wastewater, sludge and scale) prior to disposal. Confirmatory compliance sampling must be conducted on wastewater and or scale process prior to transport to an authorized facility for treatment/disposal. Representative samples shall be collected in approved containers and sent to an accredited lab for radiochemical analysis. Accurate quantification of NORM radionuclides requires specialized analytical techniques. Release limits published in Health Canada's, *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials* (**Refer to Appendix C – Table 5.1**) provide recommendations based on the radiological properties of NORM. **Liquid waste will have to meet the limits set out in the *Environmental Control Water and Sewage Regulations*, for Radium 226 and all other relevant parameters.** In determining an acceptable material management option, other hazardous properties such as chemical toxicity shall also be considered.

Surface contaminated (internal and external) equipment intended for release to third parties not licensed to accept NORM contaminated materials must meet the unrestricted release criteria of 1.0 Bq/cm² averaged over 100 cm² (200 CPM) and be decontaminated prior to release.

All shipments with an activity less than 70 Bq/g are required to have a manifest shipped with the NORM contaminated items. The manifest must contain the descriptor “**Naturally Occurring Radioactive Material**” and are subject to *Federal Transportation Regulations*. Shipments with activity above 70

Bq/g are considered radioactive and fall under the federal jurisdiction of Canadian Nuclear Safety Commission (CNSC) packaging. **Figure 1 provides a summary of disposal methods.**

Figure 1: Flow chart related to NORM disposal



*Liquid waste will have to meet the limits set out in the *Environmental Control Water and Sewage Regulations*.

In Canada, there are three provincially licensed facilities available specifically for NORM disposal:

- Unity salt cavern, Saskatchewan
- Melville salt cavern, Saskatchewan
- Silverberry Landfill, British Columbia

RECORD KEEPING

An annual report shall be submitted to the Department that summarizes assessments and analysis of scale and wastewater generated during processing. Where NORM waste is disposed of, records shall be maintained of the disposal activities.

An accurate inventory of materials must be maintained including originating location, date, activity or radiation dose levels and package contents including other hazardous properties to the materials being stored. Monthly inspections shall be performed to identify leaking or corroded containers, which must be immediately repacked or sealed

Table 3: NORM storage facility documents

- Container identification /pipe (ID # and type of container)
- Source of waste (originally generator and location)
- Surface rate of container equipment
- Type of waste (scale, sludge and / soil)
- Final destination and disposal site
- Date stored and date removed (to final disposal)
- Radionuclide present- radionuclide analysis (Ra228, Ra226. Pb210 etc)
- Details on maintenance and inspection of containers documented.
- Surface contamination level (Bq/cm²) if applicable

Additional Information can be obtained at:

1. Provincial Occupation Health and Safety: Nancy Hounsell (729-4450)
2. Radiological Characteristics Guidelines for Canadian Drinking water- Anar Baweha, Health Canada- 613-941-2355
3. *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document - Radiological Parameters* at www.healthycanadians.gc.ca/publications/healthy-living-vie-saine/water-radiological-radiologique-eau/index-eng.php; Anar Baweha, Health Canada -613-941-2355
4. Provincial Government-Water Related, Water Resources Haseen Khan 729-2535.

REFERENCES

International Association of Oil & Gas Producers, *Managing Naturally Occurring Radioactive Material NORM in the oil and gas industry*, Report 412, March 2016: Available online at , <http://www.ogp.org.uk/pubs/412.pdf>

Canadian Nuclear Safety Commission, *Naturally Occurring Radioactive Material Factsheet*, November 2014. Available online: <http://www.nuclearsafety.gc.ca/eng/resources/fact-sheets/naturally-occurring-radioactive-material.cfm>

Health Canada, *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)*, 2013. Available online: <http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/norm-mrn/index-eng.php>

Stuart Hunt and Associates Ltd., *The Origin, Detection and Management of Naturally Occurring Radioactive Materials: A training course for workers encountering NORM in the workplace.* (For reference purposes contact company).

Stewart Hunt, *A brief discussion about NORM*: Available online: http://www.ipnas.ulg.ac.be/garnir/pdf/SECURITE_SOURCES/NormNuclear.pdf

Australian Government, August 2008 Australian Radiation Protection and Nuclear Safety Agency Safety Guide: *Management of Naturally Occurring Radioactive Material (NORM)*, Available online: <http://www.arpansa.gov.au/pubs/rps/rps15.pdf>



Government of Newfoundland and Labrador
Department of Environment & Climate Change

Pollution Prevention Division
(Waste Management Section)

Re: Information required prior to issuing a Certificate of Approval for the handling and Storage of NORM waste.

An official copy of the Environmental Protection Act, SNL 2002 may be obtained from the Queen's Printer. An unofficial version of this Act is available through the Government of Newfoundland and Labrador website (www.gov.nf.ca). Approval under the EPA does not release the proponent from any other permitting or regulatory requirements under other legislation.

The following information shall be submitted to this Department prior to the issuance of a Certificate of Approval;

General Information

- The application shall request a Certificate of Approval to operate a NORM Waste Management System (WMS) which may include: storage and or processing/decontamination.
- Legal name of the proponent(s), mailing address, civic address/site location and primary contact person for the purpose of the application shall be outlined.
- A notice of the proposed waste management system shall be posted in a local newspaper once per week for three consecutive weeks *or* notice shall be served by registered mail on the occupiers of property situated within one mile of the proposed site. Persons with objections to the proposed site may address their concerns in writing to the Deputy Minister, Department of Environment & Climate Change
- Documentation to verify property ownership or lease of the property shall be provided.
- A copy of approval from the local municipal authority to operate a WMS

Site Location/Description

- Description of the geographic area to be served by the proposed operation
- A location map and a site plan survey (legal) drawing (including description and distance to adjacent Building. Plans shall show all property boundaries, buildings, roads, utility corridors, contours, drainage channels, water bodies (include private/public water supplies) rights of way, easements, forested areas and adjacent land uses and separation distances. Plans shall be certified by a **Professional Engineer**.
- Provide an accurate description of the proposed site, access road, facilities and equipment, including GPS location coordinates. Attach an original base map (1:25,000 scale) and/or recent air photos
- Site compatibility with other land uses, and any environmental sensitivity of the area must be commented and addressed.
An environmental baseline study of the proposed site may be required prior to construction to establish initial hydro-geological/geological and drainage conditions. Upon review of your application, the Department will determine as to whether a baseline study will be required.
- The location of any proposed gas/oil storage tank system(s), hazardous material storage shall be outlined. Tanks will have to be approved and /or registered.

Operational Information

- Please provide details of a NORM waste management plan, Items to be included:
 - Identification of radiation and types of NORM contamination

- EHS requirements, worker training – **consult with OHS**
 - NORM legislation (Radiation dose (limits); Investigation thresholds radiation surveys, dose assessments – **consult with OHS**
 - Worker protection (external and internal exposure) – **consult with OHS**
 - NORM radiochemical analysis
 - NORM transport and disposal requirements
 - how will equipment be decontaminated
 - how will monitoring of site be conducted
- Define the design standards that will be met by the NORM storage containers (e.g. CSA standard). Include photos and/or design drawings for storage containment vessels. Will design drawings be approved /stamped by professional engineers within province?

Insurance/Assurance Related

- A surety bond, a deposit of money, or irrevocable letter of credit shall be provided in the amount \$20,000 (original signed – format available).
- In the policy directive PPD2000-03 (December 21, 2000), the Minister established fees for the processing of applications and preparation of approvals. To be determined
- Proof of Environmental Liability Impairment Insurance and Auto Insurance (coverage against liability arising from third party bodily injury or property) shall be filed with the department.

Contingency/Emergency Plan

- A Contingency/health safety plan which is specific to the proposed operation and to the location of operation (i.e. Newfoundland and Labrador) must be submitted to the Department. Company personnel shall be briefed on the contents of this plan and any associated emergency response procedures and equipment.
- A contingency plan is a set of predetermined procedures for the reporting, containment, removal and cleanup of a contaminant(s). The plan should reduce potential health hazards, damage to property and the environment and the cost of cleanup. The plan should include such items as:
- the role of the driver in response to an incident
 - notification and alerting procedures (internal and external procedures) including provincial contacts (telephone numbers)
 - responsibilities of the on site commander
 - spill control and clean up procedures
 - restoration of the spill site
 - information on the disposal of contaminants
 - resource inventory: equipment, manpower, consultants, treating agents, expertise, contacts, emergency information systems.
 - Information on staff training (health, safety and environmental response)
 - personal protective equipment for response personnel
 - prevention of explosion fire explosion and accidental releases be dealt with?

Decommissioning plan: A plan is to be submitted which has been developed in accordance with the CCME National Guidelines for Decommissioning of Industrial Sites

In addition to the preceding requests, a site inspection of the proposed location is to be conducted by the SNL. Upon confirmed site suitability and receipt of the completed application, the information will be reviewed by the Department of Environment and Climate Change and Service NL.

Preparation of an approval is contingent upon submission of requested information and documentation. Please note that additional information may be required throughout the approval process. Approval must be issued before construction work may commence.

Should you require clarification on comments and conditions contained in this correspondence or with any other questions which may arise, please contact me @ 709-729-1771 or joangann@gov.nl.ca

APPENDIX B: WORKER SAFETY PRACTICES

The practices below deal with **worker safety** and are not the mandate of Waste Management. **Consultation with the Department of Service NL - Occupational Health and Safety** is required for all workers involved with activities dealing with NORM storage and processing/decontamination.

Measures to be considered for the reduction of internal and external exposures:

- **Internal radiation exposure (absorption, ingestion and inhalation)**
 - personal protective equipment (PPE)- disposable or nonporous clothing and footwear.
 - use of respirators.
 - no eating/drinking/smoking.
 - segregating NORM contaminated waste from non-contaminated waste, proper storage and sealing of equipment.
- **External radiation exposure**
 - minimizing time around restricted areas where NORM waste is stored.
 - increasing the distance from the source you will decrease dose.
 - using shielding with layers of lead or brick will block the radiation. *Caution shall be taken when conducting readings of tubular because the walls act as shielding.*

Dose Assessment

Readings during radiation surveys of all equipment, valves and other waste containing NORM, shall be used to determine the potential exposure workers may receive during work activities. Health Canada, NORM guidelines have adopted an investigation threshold level of 0.3 mSv/per year (0.15uSv/hour). Any measurement above this level will result in project/job dose assessment. If this level is exceeded (above natural background) operators should ensure workers shall not exceed doses greater than 1 mSv/a (0.5 uSv/Hr).

Annual cumulative dose for workers shall be considered when determining the number of hours allowed at source. Results will determine the number of hours a worker can work at source and one meter from source. Employers are responsible for completing worker dose assessments (**Table C1 shows items to be included in a dose assessment**). Workers who have the potential to be exposed to NORM may be required to wear personal monitoring badges until monitoring demonstrates that NORM is consistently in the unrestricted classification under Health Canada.

Table C1: Dose Assessment Requirements

<ul style="list-style-type: none">➤ Employee and company name➤ Year To Date received dose mSv/per year➤ Expected to exceed investigated limit (0.3 uSv/hr)➤ Expected to exceed limit 1.0 mSv/per year	<ul style="list-style-type: none">➤ Dose Background reading - uSv/hr➤ Highest dose reading at source uSv/hr”➤ Number of hours to work at source➤ Cumulative dose for year/project
--	--

NORM Storage

The principle of ALARA (As Low As Reasonably Achievable) applies to all occupational radiation exposure situations. The implementation of various safety measures/controls relating to distance, shielding and exposure time reduces your radiation exposure.

- NORM storage area must be managed and work practices established to ensure that annual exposure to incidentally exposed workers does not exceed 1.0 mSv/yr.
- Workers should receive appropriate training in the correct use of PPE (personal protective equipment) such as: wearing appropriate protective clothing, including gloves and coveralls.
- Proper hygiene shall be implemented in the NORM storage area: no eating, drinking or smoking.
- Workers are to ensure that any cuts or abrasions are thoroughly cleaned and covered and

should Workers working in dusty conditions shall be trained and wear approved and properly fitted respirators and report such items to their supervisor prior to start of work.

- There shall be a program in place to monitor hands, feet and clothing for contamination before leaving a designated NORM control area, to ensure that all workers are checked for any contamination with NORM before leaving the work area.
- Dose levels within the storage area must be recorded.
- All workers shall wear personal protective disposable coveralls (either PVC rain suit or Tychem). Discard all disposable coveralls, contaminated boots or gloves as NORM waste.
- An Emergency Response Plan is required and must meet the requirements set forth in the Occupational Health and Safety Regulations, including Sections 12(1)(e), 12(j), 38, and 39.

DECONTAMINATION OF NORM

- A safety meeting shall take place for workers reviewing hazards associated with this activity, and safety measures to be taken.
- Appropriate respirators must be worn during decontamination (refer to CSA Standard CSAZ94.4 and as amended)". Workers shall be properly fit tested and the employer shall have a respiratory protection program in place which is maintained.

RECORD KEEPING

Companies/Facility Operators are required to keep a record of the name and job category of each occupationally exposed worker in accordance to *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)*.

APPENDIX C: HEALTH CANADA'S TABLES

(Source – Tables are copied from Health Canada's NORM Guidelines)

Table 5.1 - Unconditional Derived Release Limits- Diffuse NORM Sources

	Derived Release Limits		
	Aqueous (Bq/L)	Solids Bq/g	Air Bq/m ³
Uranium-238 Series (all progeny)	1	.300	0.003
Uranium-238 (U-238, Th-234, Pa-234m, U-234)	10	10	0.05
Thorium-230	5	10	0.01
Radium-226 (in equilibrium with its progeny)	5	.300	0.05
Lead-210 (in equilibrium with bismuth-210 and polonium-210)	1	.300	0.05
Thorium-232 Series (all progeny)	1	.300	0.002
Thorium-232	1	10	0.006
Radium-228 (in equilibrium with Ac-228)	5	.300	0.005
Thorium-228 (in equilibrium with all its progeny)	1	.300	0.003
Potassium-40	n/a	17c	n/a

Notes: Table 5.1 footnote

A Pathways Considered:

- **Aquatic**
 1. Value 10x Guideline for Canadian Drinking Water Quality.
- **Terrestrial**
 1. External groundshine from soil contaminated to infinite depth.
 2. Soil-veg-ingestion/soil ingestion.
 3. Inhalation of resuspended material.
- **Air**
 1. Inhalation at concentration resulting in 0.3 mSv.
 2. Exposure factor of 25% assumed.

Assumptions:

- All radionuclides and compartments in equilibrium.
- Typical values for uptake and transfer factors.
- No allowance for hold-up time.
- 25% "occupancy" factor for solid source (groundshine, soil ingestion, resuspension), 25% 'occupancy' factor for air, and 50% of vegetable intake grown on soil.
- No correction for shielding, surface roughness.

Where more than one long-lived radionuclide is present in a sample, the appropriate sum of the ratios of the activity of each long-lived radionuclide and its corresponding Release limit, must not exceed 1, for example:

The sum of the concentration of NORM isotope A divided by the derived release limit for isotope A plus the concentration of NORM isotope B divided by the derived release limit for isotope B and so on for each of the long-lived radionuclides present in the sample until the concentration of NORM isotope N divided by the derived release limit N must be equal to or less than 1

$$\frac{\text{Concentration NORM Isotope A}}{\text{Derived Release Limit A}} + \frac{\text{Concentration NORM Isotope B}}{\text{Derived Release Limit B}} + \dots + \frac{\text{Concentration NORM Isotope N}}{\text{Derived Release Limit N}} \leq 1$$

- b) Aqueous Release limits ~10x Guidelines for Canadian Drinking Water Quality. Subsequent dilution of the release is assumed. Refer to the Provincial Drinking Water Standard where planned diffuse NORM releases must meet provincial drinking water standards. (See reference)
- c) Natural abundance of Potassium 40 in potassium chloride.
- d) No aqueous release limit is needed as potassium content of the body is under homeostatic control, and is not influenced by environmental levels.

Table 5.3 - Surface Contamination Unconditional Derived Release Limits - Discrete NORM Sources

Property	Limit
Dose Rate	0.5 µSv/h at 50 cm.
Surface Contamination	1 Bq/cm ² averaged over a 100 cm ² area

Notes:

1. A thin window radiation detector is recommended when monitoring beta/gamma sources of surface contamination.
2. Table 5.3 release limits are only applicable to fixed surface contamination. Loose surface contamination must be completely removed or all accessible surfaces stripped to ensure complete removal.
3. In most cases, decontamination efforts which meet beta surface contamination limits will concurrently provide for the control of mixed alpha / beta / gamma sources.



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sécurité... notre priorité.*

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Prepared by the Canadian NORM Working
Group of the Federal Provincial Territorial
Radiation Protection Committee

Revised 2011

Canada 

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Health Canada is the federal department responsible for helping the people of Canada maintain and improve their health. We assess the safety of drugs and many consumer products, help improve the safety of food, and provide information to Canadians to help them make healthy decisions. We provide health services to First Nations people and to Inuit communities. We work with the provinces to ensure our health care system serves the needs of Canadians.

Également disponible en français sous le titre :
Lignes directrices canadiennes pour la gestion des matières radioactives naturelles (MRN)

To obtain additional information, please contact:

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Preface

The NORM Working Group, a working group of the Federal Provincial Territorial Radiation Protection Committee, represents the interests of provincial and territorial regulators and includes affected industries in the petroleum production, fertilizer manufacturing and metal recycling industry sectors. With the support and encouragement of Health Canada and the Canadian Nuclear Safety Commission, these *Guidelines* are the result of their efforts.

Comments or suggestions concerning the *Guidelines* should be sent to:

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Abbreviations Used in the *Guidelines*

ALARA	An acronym for “As Low As Reasonably Achievable”, social and economic factors being taken into account. ALARA is a guiding principle in radiation protection, and encourages managers to reduce dose levels as much as possible, even if they are already meeting allowable levels.
ALI	Annual Limit on Intake
BEIR	(United States National Academy of Science Committee on the) Biological Effects of Ionizing Radiation
CNSC	Canadian Nuclear Safety Commission is the federal agency that licenses and regulates nuclear facilities and materials. The CNSC is the successor to the Atomic Energy Control Board (AECB).
DC	Dose Coefficient
DRL	Derived Release Limit
DWL	Derived Working Limit
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
NCRP	National Council on Radiation Protection and Measurements
NDR	National Dosimetry Registry
NORM	Naturally Occurring Radioactive Material
PTNSR	Packing and Transport of Nuclear Substances Regulations
SCO	Surface Contaminated Object
TDGR	Transportation of Dangerous Goods Regulations
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
UDRL	Unconditional Derived Release Limit
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

Introduction

The Canadian Nuclear Safety Commission (CNSC), formerly the Atomic Energy Control Board (AECB), has legislative control of nuclear fuel cycle materials and man-made radionuclides. However, naturally occurring radioactive material (NORM) is exempt from CNSC jurisdiction except for the import, export and transport of the material. Therefore, jurisdiction over use and radiation exposure to NORM rests with each Canadian province and territory.

It has been the practice for companies that encounter challenges associated with NORM to seek advice on safety procedures from provincial and territorial regulatory agencies. Such advice has been given on an *ad hoc* basis, leading to inconsistencies in the interpretation and application of radiation safety standards across Canada.

The Federal Provincial Territorial Radiation Protection Committee (FPTRPC), a Canadian intergovernmental committee established to support federal, provincial and territorial radiation protection agencies in carrying out their respective mandates, recognizes that the potential radiation hazards from NORM are the same as those from radioactive materials controlled by the CNSC. The basic principle of these guidelines is that where workers or the public are exposed to additional sources or modes of radiation exposure because of activities involving NORM, the same radiation protection standards should be applied as for CNSC regulated activities. This applies to situations where NORM is in its natural state and to cases in which the concentration of NORM material has been increased by processing.

However, in practice there may also be situations where existing natural background radiation is significant quite apart from any activities involving the use of NORM. The issue of whether human intervention is required to reduce such natural radiation levels is quite separate from the issues discussed in these *Guidelines* and the reader is referred to ICRP 65 for a discussion of when such intervention might be warranted.

To that end, the Canadian NORM Working Group has, on behalf of the FPTRPC, produced the *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)*. The *Guidelines* are an extension of the work done by the Western Canadian Committee on Naturally Occurring Radioactive Materials (NORM) published in August 1995 as the *Guidelines for the Handling of Naturally Occurring Radioactive Materials (NORM) in Western Canada*.⁽¹⁾ The differences between the Canadian Guidelines and the Western Canadian Guidelines reflect changes in national and international radiation protection practices and consensus standards for NORM classification and management since 1995.

The *Canadian Guidelines* set out principles and procedures for the detection, classification, handling and material management of NORM in Canada, and also include guidance for compliance with federal transportation regulations. These *Guidelines* provide the framework for the development of more detailed NORM management practices and guidelines by regulatory authorities, affected industries and specific workplaces. A separate section outlines the basic science of radioactivity and explains the technical terms and concepts that are used throughout the *Guidelines*. There is also a glossary at the end of the document for quick reference and definition.

1 NORM as a Radiation Concern

1.1 Definition

NORM is an acronym for *naturally occurring radioactive materials*, which include radioactive elements found in the environment. Long-lived radioactive elements of interest include uranium, thorium and potassium, and any of their radioactive decay products, such as radium and radon. These elements have always been present in the earth's crust and within the tissues of all living beings.

Although the concentration of NORM in most natural substances is low, higher concentrations may arise as the result of human activities. For example, calcium scale precipitated from oil recovery brine may contain radium at much greater concentrations than the water source itself. The processing of raw materials by many resource-based industries may increase the concentration of radioactive substances in those materials, to levels at which special precautions are needed for handling, storing, transporting, and disposal of material, by-products, end-products or process equipment.

1.2 Purpose of the Canadian NORM Guidelines

As NORM is not part of the nuclear fuel cycle, it does not come under the control of the CNSC, which licenses and controls radioactive materials associated with the nuclear fuel cycle and artificially produced radionuclides. NORM-related activities therefore fall under the jurisdiction of the provinces and territories. This has led to inconsistent application of radiation protection standards with numerous agencies involved as materials cross jurisdictional boundaries. For example, transportation of a NORM material for disposal involves:

- Provincial/Territorial Health, Labour and Radiation Regulatory Agencies for worker and public exposure;
- Provincial Environmental Regulatory Agencies for disposal options;
- The CNSC for transport of radioactive material.

Note: In its legislation, the CNSC uses the term Naturally Occurring Nuclear Substances instead of NORM.

Accordingly, the *Guidelines* were developed to:

- ensure adequate control of NORM encountered by affected industries;
- harmonize standards;
- reduce jurisdictional gaps or overlap.

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.

A major principle in radiation dose control is that if doses can be reduced by reasonable actions, those actions should be taken. As even low doses of radiation exposure may produce harmful effects, reducing low doses of radiation may be beneficial. The goal is that doses should be *As Low As Reasonably Achievable*, economic and social factors being taken into consideration. This principle is usually referred to by the acronym ALARA.

1.3 Industries with NORM Radiation

There are industries where NORM may be present in amounts sufficient to cause significant radiation doses to workers that require the application of radiation protection practices to reduce radiation doses. Such industries include:

Mineral Extraction and Processing: NORM may be released or concentrated in a process stream during the processing of ore, such as in the phosphate fertilizer industry and the abrasives and refractory industries.

Oil and Gas Production: NORM may be found in the liquids and gases from hydrocarbon-bearing geological formations.

Metal Recycling: NORM-contaminated materials can be redistributed to other industries resulting in the formation of new NORM-contaminated products.

Forest Products and Thermal-Electric Production: mineral ashes left from combustion may concentrate small amounts of NORM present naturally in plant materials and in coal.

Water Treatment Facilities: fresh or waste water is treated through sorptive media or ion-exchange resins to remove minerals and other impurities from the water being treated and may release radon (geothermal sources, fish hatcheries).

Tunnelling and Underground Workings: in areas where small amounts of indigenous radioactive minerals or gases may be present, such as in underground caverns, electrical vaults, tunnels, or sewer systems.

1.4 Description and Sources of NORM

1.4.1 Background Radiation

Life on earth has always been exposed to natural radiation from the environment, also referred to as background radiation. The main sources of this radiation are cosmic radiation from the sun and outer space, and terrestrial radiation from radioactive elements in the earth's crust. A common example of terrestrial radiation source is radon gas, which comes from uranium in the soil and can accumulate in buildings.

1.4.2 Radionuclides and Ionizing Radiation

Chemical elements are characterized by the number of protons in the nucleus of their atoms. Atoms also contain other "sub-atomic particles" such as neutrons and electrons. The number of protons in the atoms of a given element is constant, but the number of neutrons can differ. Atoms of an element that have different numbers of neutrons are called isotopes of that element, though they all behave chemically the same way. Isotopes of an element are referred to by the name of the element followed by the number of the isotope's nucleons (protons + neutrons). Uranium, for example, always has 92 protons, but it has a number of isotopes identified by the number of their nucleons, such as uranium-235 and uranium-238.

Most common isotopes of chemical elements are stable; that is, the balance of protons and neutrons in the nucleus of their atoms never changes. In isotopes of some elements, however, the balance of protons and neutrons in the atom makes the atom unstable, so it ejects one or more particles and excess energy from the nucleus to become more stable. This process is called nuclear disintegration. The particles or high-energy rays are called "ionizing radiation" because they ionize, or change the physical and chemical structure of, other atoms of matter they pass through. Elements that emit ionizing radiation are called radioactive; in some cases, one or more isotopes of an element are radioactive, and are called radioisotopes, or radionuclides.

1.4.3 Half-Life and the Radioactive Decay Series

A radionuclide can be identified by the characteristics of the radiation it emits. These characteristics include the decay rate, or half-life of the radionuclide, and the type and energy of radiation emitted.

The rate at which particles are emitted is expressed by the half-life of the radionuclide. The half-life is the length of time it takes for half of a substance's atoms to 'decay' to a more stable form, or to reduce the radioactivity by half. The half-life can be as short as a fraction of a second or as long as billions of years. As a radionuclide decays, it becomes an isotope of another element. If this new isotope is also radioactive it decays further. Thus there can develop a "decay series." The two most common NORM decay series are the uranium-238 and the thorium-232 series. Figure 1.1 lists the radioisotopes associated with the uranium and thorium radioactive decay series and potassium, and also gives the chemical symbol for each element and isotope.

Table 1.1
Chemical Symbols and Important Characteristics of the U-238, Th-232 Radioactive Decay Series and K-40

Uranium 238 Series			
NORM Nuclide	Symbol	Half-life	Major Emissions
Uranium 238	²³⁸ U	4.5x10 ⁹ y	α
Thorium 234	²³⁴ Th	24.0 d	β, γ
Protactinium 234m	^{234m} Pa	1.2 m	β, γ
Uranium 234	²³⁴ U	2.5x10 ⁵ y	α, γ
Thorium 230	²³⁰ Th	7.7x10 ⁴ y	α, γ
Radium 226	²²⁶ Ra	1.6x10 ³ y	α, γ
Radon 222	²²² Rn	3.83 d	α
Polonium 218	²¹⁸ Po	3.1 m	α
Lead 214	²¹⁴ Pb	27 m	β, γ
Bismuth 214	²¹⁴ Bi	20 m	β, γ
Polonium 214	²¹⁴ Po	1.6x10 ⁻⁴ s	α, γ
Lead 210	²¹⁰ Pb	22.3 y	β, γ
Bismuth 210	²¹⁰ Bi	5.01 d	β
Polonium 210	²¹⁰ Po	138 d	α
Lead 206	²⁰⁶Pb	stable	none

Thorium 232 Series			
NORM Nuclide	Symbol	Half-Life	Major Emissions
Thorium 232	²³² Th	1.4x10 ¹⁰ y	α
Radium 228	²²⁸ Ra	5.7 y	β
Actinium 228	²²⁸ Ac	6.1 h	β, γ
Thorium 228	²²⁸ Th	1.9 y	α, γ
Radium 224	²²⁴ Ra	3.7 d	α, γ
Radon 220	²²⁰ Rn	55.6 s	α
Polonium 216	²¹⁶ Po	0.15 s	α
Lead 212	²¹² Pb	10.6 h	β, γ

Bismuth 212	^{212}Bi	61 m	α, β, γ
Polonium 212 (65%)	^{212}Po	3×10^{-7} s	α
Thallium 208 (35%)	^{208}Tl	3.1 m	β, γ
Lead 208	^{208}Pb	stable	none
Potassium -40			
Potassium 40	^{40}K	1.3×10^9 y	β, γ

Key:

Example: **Bismuth 212** ^{212}Bi **61 m** α, β, γ

212: Mass number for Bismuth 212

Bi: Chemical symbol for Bismuth

61 m: Radioactive half-life of 61 minutes
(y = years; d = days; h = hours;
m = minutes; s = seconds)

α : Alpha decay (emission)

β : Beta decay (emission)

γ : Gamma (emission)

1.4.4 Radioactive Equilibrium

The final member of a decay series is stable. The first member (the “parent radionuclide”) is almost always very long-lived - it has a long half-life. When all the members of a decay series (the parent radionuclide and its “progeny”) are “in equilibrium” they all decay at the same rate - the rate at which each in turn is being produced - and every radioactive element or radioactive progeny in the series has the same amount of radioactivity. If such radioactive material is processed chemically or otherwise disturbed, the equilibrium is disrupted.

1.4.5 Types of Radiation

There are three basic types of radiation that may be emitted by NORM:

- **alpha** (α) radiation is made up of heavy, charged particles that cannot penetrate very far, even in air. They can be stopped by a piece of paper.
- **beta** (β) radiation consists of lighter charged particles than alpha particles, that travel faster and are thus more penetrating than alpha radiation. Beta radiation can be stopped by a few centimetres of plywood.

- **gamma** (γ) radiation consists of high-energy rays, and is very penetrating. It can be stopped by a metre of concrete or several metres of water.

1.5 Fundamental Radiation Protection Quantities

There are two fundamental quantities:

Becquerel (= Activity). The becquerel (Bq) measures the quantity of radioactivity present without consideration for what kind of radiation is emitted. 1 Bq = 1 nuclear transformation (disintegration) per second.

Sievert: Effective Dose (= Biological Effect). Different types of radiation have different penetrating power, and different parts of the body have different sensitivities to radiation. Dose assessment therefore requires knowledge of the type and amount of radiation and the biological sensitivity of the body part exposed. The sievert (Sv) is the unit of Effective Dose of radiation, and accounts for the total effect of different types of radiation on different parts of the body. Most occupational doses are in the millisievert range, or mSv. Regulations express the dose on a yearly basis, as millisieverts per annum or mSv/a.

An individual may receive an “internal” exposure to a radioactive substance, by inhaling radioactive gas or particles suspended in the air, or by ingesting radioactive dust. The material may remain in the body for some time after the intake, giving a dose. The life-time dose that will be received from an internal exposure is the “committed dose,” also expressed in sieverts.

1.6 Background Radiation Dose summary

Figure 1.2 is a pie chart showing the size in percent of each component of the background radiation dose received by the average Canadian.⁽²⁾ Sources of natural radiation can be classified into three groups: the dose that comes from direct cosmic radiation that arrives at the earth’s surface from the sun and outer space; the dose from environmental radiation, which comes from the natural radioactivity at the earth’s surface; and internal radiation.

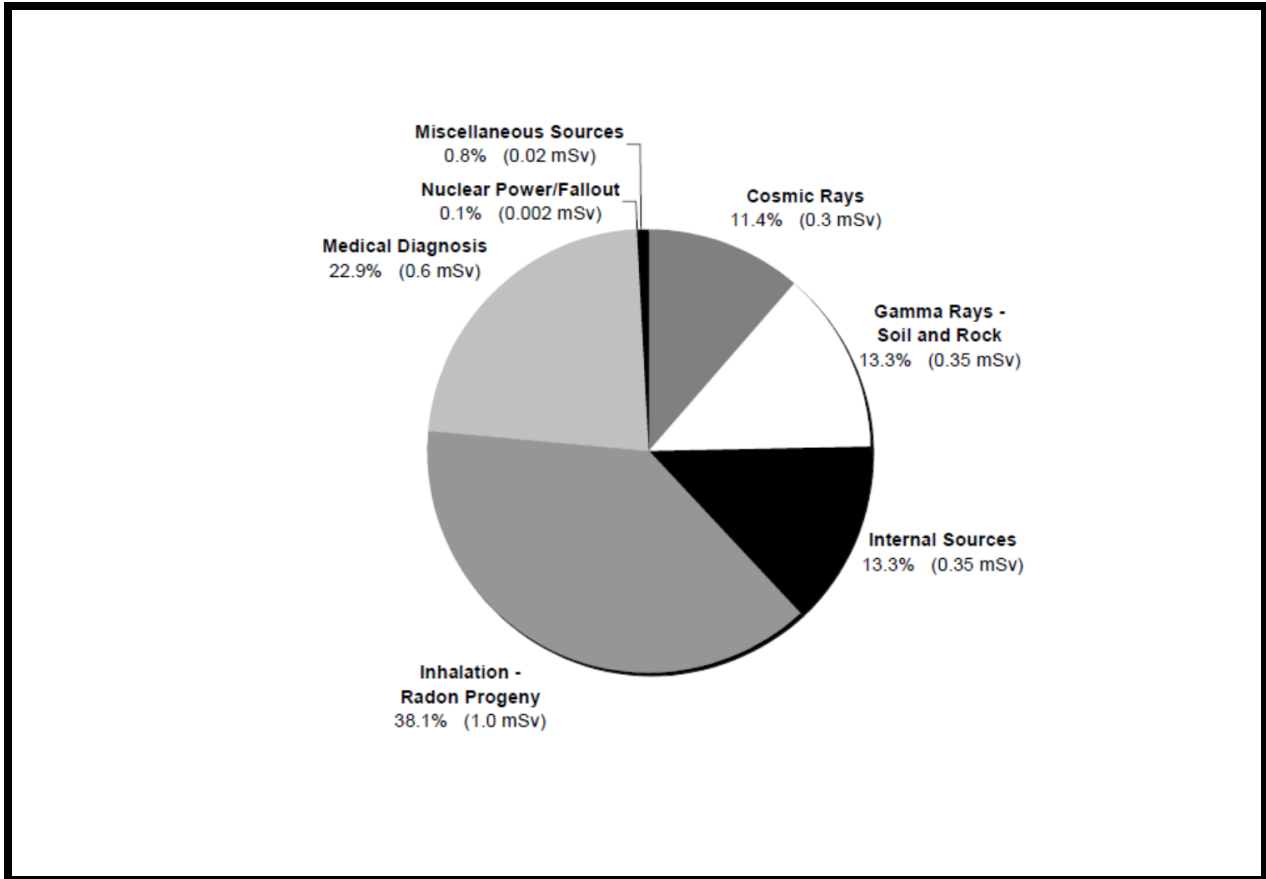
Cosmic radiation varies with elevation above sea level, but contributes about 0.3 mSv/a over most of Canada.

The range of gamma dose rates from naturally occurring radionuclides in the uranium and thorium series, and potassium-40 present in typical soil is:

- 0.045 - 0.09 mSv/a for the uranium-238 series;
- 0.09 - 0.15 mSv/a for the thorium-232 series;
- 0.09 - 0.15 mSv/a from potassium-40.

The typical dose rate from the two series and potassium-40 is 0.35 mSv/a.

Figure 1.1
Average Annual Radiation Dose to Canadians
(Average Total Dose of 2.62 mSv per year)



Source: Canada; Living with Radiation, AECB, 1995.

There is an average internal dose of about 1.0 mSv from the inhalation of radon progeny; but the dose varies greatly with the geological composition of the environment. For example, the average dose from radon progeny in Vancouver is 0.2 mSv/a, but in Winnipeg it is 2.2 mSv/a.

Another source of internal radiation is from a radioactive isotope of potassium: muscle tissue contains potassium, of which 0.0118 % is potassium-40, a natural gamma and beta ray emitter which contributes about 0.35 mSv per year.

In total, a Canadian may receive a range of annual doses from background radiation from 1.2 mSv/a to 3.2 mSv/a based on geographical location. The average Canadian receives a typical annual dose of approximately 2.0 mSv from background radiation.

Clearly, as radiation doses from NORM cannot be prevented, the question is: **At what incremental dose should we begin to apply radiation protection practices to NORM?** The *Guidelines* have been developed to help answer this question.

2 The NORM Standards — Basis and Criteria

2.1 Uniformity of Protection

The basic principle of these guidelines is that the same radiation exposure criteria should be applied where workers or the public are exposed to new sources or modes of radiation from activities involving NORM, as for radiation exposure from CNSC regulated activities. This applies to cases where NORM is in its natural state and to cases in which the concentration of NORM material has been increased by processing.

2.2 Guideline Basis

The *Guidelines* are based on the most recent international standards recommended by the International Commission on Radiological Protection (ICRP) and CNSC regulations. The recommendations of the ICRP represent international consensus on radiation protection standards and provide the basis for regulatory control of radioactive materials in virtually all countries of the world. As these regulations and standards are subject to periodic amendment, the *Guidelines* may also be updated to reflect amendments to accepted national and international radiation protection practices. The ICRP and International Atomic Energy Agency (IAEA) radiation protection philosophy and recommendations of significance for NORM in Canada are contained in ICRP reports 60⁽³⁾, 65⁽⁴⁾, 68⁽⁵⁾, 72⁽⁶⁾ and 77⁽⁷⁾ and IAEA Safety Series 115⁽⁸⁾.

2.3 The Acceptability of Occupational Risks in Industry

The ICRP reviews estimates of radiation risk from every available source, particularly the work of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the United States National Academy of Science Committee on the Biological Effects of Ionizing Radiation (BEIR). The reports of the ICRP go further than these sources, in that the ICRP recommends permissible exposures for workers while the other bodies merely estimate the risks associated with radiation exposure.

The ICRP believes that any exposure to ionizing radiation may be potentially harmful to health, and advocates three fundamental principles for managing radiation exposures:

- **Justification** — No activity involving ionizing radiation for any purpose can be justified unless it is possible to demonstrate that it will lead to a positive net benefit.
- **Optimization** — All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into consideration (the ALARA principle).
- **Limitation** — The maximum acceptable occupational exposure of any individual must not involve a radiation risk to that individual greater than the risk that arises in working in what is generally regarded as a "safe" industry.

The ICRP recognizes that everyone is subject to a significant background radiation exposure. However, even smaller-than-background doses from occupational practices are unjustifiable if there is no associated benefit, or they can be readily avoided.

2.4 Recommended Radiation Dose Limits

It is the recommendation of the FPTRPC that the annual incremental effective dose to persons exposed to NORM as the result of a work practice be limited to the values given in Table 2.1.

These dose limits are the foundation for all other radiation protection program recommendations contained in the *Guidelines*; are harmonized with the radiation dose limits recommended by the CNSC for nuclear fuel cycle; and incorporate the recommendations of ICRP Publication 103⁽¹⁷⁾.

2.4.1 Incremental Dose

Dose limits in this document are defined in terms of incremental dose, which is the dose resulting from the work practice in question. The natural background radiation, with the exception of radon (see section 4.2), is excluded from the dose limitations. Radiation dose arising from the application of medical procedures is also excluded from the dose limitations.

2.4.2 Effective Dose

The ICRP defines the effective dose as the sum of all tissue equivalent doses multiplied by the appropriate tissue weighting factors associated with each respective tissue. The effective dose accumulated over a given period includes:

- a. the effective dose from external sources, and
- b. the committed effective dose from intakes of radionuclides in that period.

**Table 2.1
Radiation Dose Limits**

Affected Group	Annual Effective Dose Limit (mSv) ^(a)	Five Year Cumulative Dose Limit (mSv)
Occupationally Exposed Workers ^(b)	20 ^(c)	100
Incidentally Exposed Workers and Members of the Public	1	5

Notes:

- (a) These limits are exclusive of natural background and medical exposures. Refer to Appendix D for guidance on dose limit calculations.

- (b) For the balance of a known pregnancy, the effective dose to an occupationally exposed worker must be limited to 4 mSv as stipulated in the “Radiation Protection Regulations”, Canadian Nuclear Safety Act. This limit may differ from corresponding dose limits specified in current provincial legislation applicable for exposure to sources of x-rays.
- (c) For occupationally exposed workers, a maximum dose of 50 mSv in one year is allowed, provided that the total effective dose of 100 mSv over a five-year period is maintained. This translates into an average limit of 20 mSv/a.

Occupationally Exposed Workers are employees who are exposed to NORM sources of radiation as a result of their regular duties. They are classified as NORM Workers working in an occupational exposure environment, and their average annual effective dose should not exceed 20 mSv (see Table 2.1 note c, for exception).

Incidentally Exposed Workers are employees whose regular duties do not include exposure to NORM sources of radiation. They are considered as members of the public who work in an occupational exposure environment and, as such, the annual effective dose limit for these workers is 1 mSv.

Members of the Public are persons who have no occupational exposure to NORM. The annual effective dose limit for members of the public is 1 mSv. For the control of public exposure an appropriate value for the dose constraint is 0.3 mSv in a year.

2.4.3 Dose Constraint

A dose constraint is an upper bound on the annual dose that members of the public or incidentally exposed workers should receive from the planned operation of any source. To ensure that the public and incidentally exposed workers do not exceed the annual dose limit of 1 mSv, the ICRP⁽¹⁷⁾ and the IAEA⁽⁸⁾ suggest the use of a dose constraint. The dose constraint would allow for exposures from other sources without the annual limit being exceeded. The retrospective finding that a dose constraint, as opposed to a dose limit, has been exceeded does not imply a failure to comply with the recommendations of the guidelines. Rather it should call for a reassessment of the effectiveness of the program.

ICRP⁽¹⁷⁾ suggests that for the control of public exposure an appropriate value for the dose constraint is 0.3 mSv in a year. In keeping with this suggestion the Canadian NORM guidelines have adopted 0.3 mSv/a as its first investigation level. Tables 5.1 and 5.2 list the amounts of radioactive materials that if released to the environment without further controls will not cause doses in excess of 0.3 mSv/a.

3 Development of a NORM Management Program

3.1 The NORM Program Classifications

The NORM program classifications summarize the requirements for managing NORM. The worksite classification is set by the maximum annual dose received by both members of the public and workers at the worksite (Figure 3.1). The classification of an individual NORM source is set by the annual dose that may be received by a member of the public from exposure to the shipment or disposal practice.

Estimates should be made of the effective dose to workers and the public resulting from the following exposure pathways:

- External gamma exposure.
- Ingestion of NORM-containing materials.
- Inhalation of NORM-containing dust.
- Inhalation of radon gas and its radioactive decay products.

The highest individual dose determines the NORM Management classification. Guidance on effective dose calculations can be found in Appendix D.

It is strongly recommended that a person knowledgeable in radiation protection conduct the worksite radiological evaluation. A list of radiation protection consultants can be obtained from the appropriate provincial or territorial government contact. A list of government contacts can be found in Appendix B.

3.2 NORM Classification/Thresholds

3.2.1 Investigation Threshold

An incremental dose of 0.3 mSv/a, the dose constraint value set in section 2.4.3, is adopted as the NORM Investigation Threshold. Where doses to workers or members of the public may exceed this value, a site-specific assessment should be carried out.

3.2.2 NORM Management Threshold

An assessed incremental dose to the public or workers of greater than 0.3 mSv/a, the dose constraint value set in section 2.4.3 and the Investigation Threshold, is adopted as the NORM Management Threshold.

3.2.3 Dose Management Threshold

An assessed incremental dose of 1 mSv/a to a worker is adopted as the Dose Management Threshold.

3.2.4 Radiation Protection Management Threshold

An assessed or measured incremental worker dose of 5 mSv/a is adopted as the Radiation Protection Management Threshold.

3.3 Introduction of a NORM Program

The steps to determine the type of NORM Management program at a workplace are given below. Figure 3.1 summarizes the process in a flow-chart.

3.3.1 Initial Review

If a workplace falls in one of the NORM-prone industries noted in Section 1.3:

- stores, handles or disposes of materials containing amounts of natural radioactive substances in excess of amounts in Tables 5.1 for diffuse NORM or 5.2 for discrete NORM; or
- has suspected incremental effective dose rates in excess of 0.3 mSv/a;

the NORM Investigation Threshold may be exceeded. A dose assessment should be carried out.

3.3.2 Radiation Dose Assessment

Estimate doses to members of the public, and workers by conducting a radiation survey of the workplace/worksites. The survey should include evaluations of both gamma dose-rates and airborne radioactivity as required.

Workers with estimated doses in excess of 1 mSv/a are classified as occupationally exposed workers.

Estimate doses to members of the public from feedstock, product and waste transport, storage and disposal. Radiochemical analysis of feed stock, products and waste materials may be needed.

3.3.3 Evaluation and Program Classification

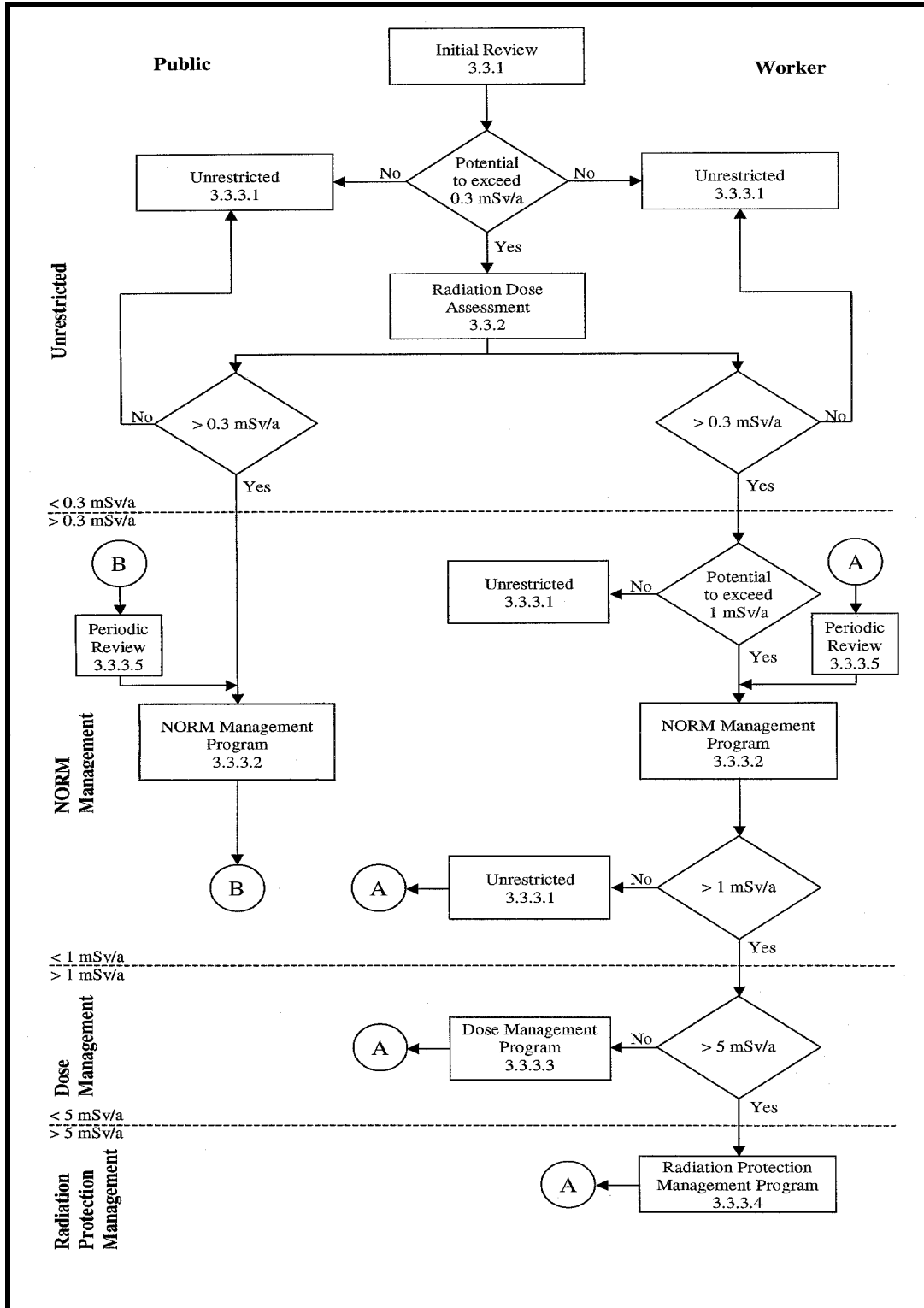
3.3.3.1 Unrestricted Classification

Where the estimated incremental annual effective dose to the public is less than 0.3 mSv/a and to the worker is less than 1.0 mSv/a, the NORM program classification is **Unrestricted**. No further action is needed to control doses or materials.

3.3.3.2 NORM Management Classification

Where the estimated incremental annual effective dose to members of the public or incidental workers is greater than the investigation threshold of 0.3 mSv/a, the NORM classification is ***NORM Management***. Public access would need to be restricted. However, worker access would be unrestricted. Depending on the circumstances and the source of the dose, the NORM Management Program may include:

**Figure 3.1
NORM Classification Flowchart**



- Introduction of incidentally exposed worker access restrictions.
- Introduction of shipping and/or material management.
- Changes in work practices.

Where the work site, feed and waste materials are subject to change, the work site, feed and waste material should be reviewed periodically to verify that conditions have not changed.

3.3.3.3 Dose Management

Where the estimated incremental annual effective dose to an occupationally exposed worker is greater than the dose management threshold of 1 mSv/a, the NORM classification is ***Dose Management***.

The program should include:

- Worker notification of radiation sources.
- Consideration of work procedures and protective clothing to limit worker dose from NORM.
- Application of engineering controls where appropriate (see 4.3.3).
- Training to control and reduce worker dose.
- Introduction of a worker radiation dose estimate program. Doses may be estimated from the dose rate in each working area and the time spent in each area or by personal monitoring.
- Reporting of worker doses to the National Dose Registry (NDR) through the dosimetry service provider (see address in Appendix B).

Assess the work site periodically to measure changes in conditions and to facilitate worker dose calculations.

3.3.3.4 Radiation Protection Management

Estimated Annual Effective Dose

Where the estimated annual effective dose to an occupationally exposed worker is greater than 5 mSv/a, the NORM classification is ***Radiation Protection Management***. In addition to the requirements of the Dose Management Program, the following should be included:

- Introduce a formal radiation protection program as described in Appendix F. This program is similar to the formal program required by the CNSC for nuclear energy workers exceeding 5 mSv/a.

- Place those workers estimated to exceed 5 mSv/a in a personal radiation dosimetry program meeting the requirements of S-106 revision 1, Technical and Quality Assurance Requirements for Dosimetry Services.⁽⁹⁾
- Provide protective equipment, clothing and work procedures to reduce worker dose and the spread of contamination.

Measured Annual Effective Dose

Where the measured annual effective dose reported by a personal radiation dosimetry program is greater than 5 mSv/a, the NORM classification is ***Radiation Protection Management***. The program should include the following additional steps:

- Use engineering controls and provide protective equipment designed to reduce worker dose as required.
- Ensure that workers do not exceed the five-year average occupational dose limit of 20 mSv/a.

Assess the work site periodically to measure changes in conditions and to facilitate worker dose calculations.

3.3.3.5 Periodic Review

Whenever a NORM Management, Dose Management or Radiation Protection Management Program has been implemented, a periodic review is needed. The review is to determine if there have been changes to the system that may affect the radiation dose, to monitor the effectiveness of the NORM program and to determine if modifications are required. The frequency of the periodic review will depend on the ability of conditions to change and the NORM program.

3.3.4 ALARA

The goal is that doses should be ALARA, economic and societal factors being taken into account. From the time a NORM accumulation is expected to the implementation of a NORM Program, the ALARA principle should be the prime decision making criterion used to ensure minimal public and worker radiation dose.

4 Derived Working Limits (DWLs) for NORM

Derived Working Limits (DWLs) have been determined from the annual radiation dose limits to assist in dose assessment. The DWLs provide an estimate of dose from the quantities that may be directly measured in the workplace. A Radiation Assessment program may compare measurement results to DWLs.

4.1 Gamma Radiation Dose Rate

4.1.1 Investigation Threshold

The occupational dose-rate that will give an incremental gamma radiation dose of 0.3 mSv/a is 0.15 $\mu\text{Sv/h}$. The DWL for the gamma Investigation Threshold is an incremental dose-rate above off-site background of 0.15 $\mu\text{Sv/h}$.

4.1.2 Dose Management Threshold

The occupational dose-rate that will give an incremental gamma radiation dose of 1 mSv/a is 0.5 $\mu\text{Sv/h}$. The DWL for the gamma Dose Management Threshold is an incremental dose-rate of 0.5 $\mu\text{Sv/h}$.

4.1.3 Radiation Protection Threshold

There is no DWL for the gamma Radiation Protection Threshold as doses are expected to be derived by dosimetry measurement/estimation.

4.2 Radon Concentration

4.2.1 Introduction

Radon is a radioactive gas produced by the decay of radium isotopes in both the uranium and thorium radioactive decay series (see Figure 1.1). As it is a gas, radon can be carried away from its origin by air or water flows, and released into workplace air. Usually radon-222 is the only isotope present in high enough concentrations to provide a significant dose, but radon-220 (thoron) can be present where thorium is handled or stored.

Although elevated radon concentrations from natural causes are common in buildings, it is not the intention of these *Guidelines* to provide guidance on the management of radon in other than workplace settings. Information on public/residential radon exposure guidelines can be obtained from *Radon – Reduction Guide for Canadians*⁽¹⁰⁾ published by Health Canada.

Radon released from soil beneath a building gives rise to an average indoor background concentration of about 45 Bq/m³, but much higher values are possible in some areas. This concentration is variable with time; therefore long-term assessment measurements are recommended. In excavations and tunneling the industrial practice releases radon from the soil, so there can be no distinction between background radon and that introduced or released by the

industrial practice (practice radon).

As a result, the recommendations for radon are modified to take practical constraints into account. As background radon generally cannot be distinguished from radon generated by a workplace the dose limits given here are based on TOTAL dose from radon exposure not the INCREMENTAL dose from the practice as used elsewhere in these *Guidelines*.

The dose from radon can be estimated either from the radon gas concentration (Bq/m^3), or from the progeny energy concentration (joules per cubic metre (J/m^3)). On grounds of cost and convenience, it is recommended that radon-222 concentration be the preferred method for screening measurements. The only approved personal dosimetry system measures progeny concentration (J/m^3), therefore dose assessment as required in a Radiation Protection Management Program must be evaluated on that basis. The dose from thoron can only be estimated from progeny concentration.

Conversion factors relating dose from exposure to radon concentration and from progeny energy concentration are given in Appendix C. The assumptions and uncertainties in these conversion factors are described in ICRP Publication 65.⁽⁴⁾ Other relationships between gas and progeny measurements are also given in Appendix C (see also reference 18).

4.2.2 Investigation Derived Working Limit for Radon

As radon concentration can vary considerably it is recommended that all workplaces be assessed for potential elevated levels. The DWL for radon is 200 Bq/m^3 . The Unrestricted Classification therefore applies to all circumstances where the average radon concentration is less than 200 Bq/m^3 . Where the annual average concentration of radon gas is expected to be above 200 Bq/m^3 , measurements should be made to estimate the average annual radon gas concentration.

4.2.3 NORM Management for Radon

Where the estimated annual average concentration of radon gas in an occupied area is more than 200 Bq/m^3 but less than 800 Bq/m^3 , the NORM Classification is NORM Management. Steps to reduce this exposure should be taken and include:

- introduction of public and incidentally exposed worker access controls;
- changes in work practices; and
- reducing the radon concentration levels to below 200 Bq/m^3 .

The work site should be reviewed periodically to verify that conditions have not changed.

4.2.4 Radiation Protection Management for Radon

The DWL for the radon-222 Radiation Protection Management threshold is an average annual radon concentration of 800 Bq/m³. Where the estimated annual average concentration of radon gas is more than 800 Bq/m³, the NORM Classification is Radiation Protection Management. A Radiation Protection Management program as described in section 3.3.3.4 should be implemented. The Radiation Protection Management Program requires the initiation of a dose monitoring program. Where possible, the program should include steps to reduce the radon concentration levels to below 200 Bq/m³.

4.3 Annual Limit on Intake (ALI)

The Annual Limit on Intake (ALI) is the amount of radioactive material a worker can ingest or inhale each year, that will deliver an annual effective dose of 20 mSv. ALI values are derived from dose coefficient (DC) values, developed by the ICRP. They are based on a critical review of available research on the estimation of radiation dose delivered to specific organs and tissues which arise from an intake of a given quantity of the radionuclide.

Intake parameters (breathing rate, particle size etc.) are different for occupational or public exposure conditions so there are different DC values for occupational (DC_w) or public (DC_p) exposure.

4.3.1 Occupational ALIs

Two groups of workers must be considered in assigning ALIs:

- **Occupationally Exposed Workers** are employees who are exposed to NORM sources of radiation through their regular duties. They are classified as NORM Workers working in an occupational exposure environment, and their average annual effective dose must not exceed 20 mSv.
- **Incidentally Exposed Workers** are other employees whose regular duties do not include exposure to NORM sources of radiation. They are considered as members of the public who work in an occupational exposure environment and, as such, the annual effective dose limit for these workers is 1 mSv.

Table 4.1 shows DC_w and ALI values for NORM workers for significant NORM radionuclides. The DC_w values are from ICRP Publication 68⁽⁵⁾, and are based on an average effective dose limit of 20 mSv per year.

Appropriate ALI values for incidentally exposed workers are 1/20 of the ALI values listed in Table 4.1.

**Table 4.1
Radon and NORM Program Classifications^(a)**

Average Annual Concentration	NORM Program Classification
800 – 3000 Bq/m ³	Radiation Protection Management
200 – 800 Bq/m ³	NORM Management
Background – 200 Bq/m ³	Unrestricted

Notes:

- (a) Control of Radon 222 and its progeny within the values given in Figure 4.1 will concurrently control Radon 220 and its progeny within applicable limits.
- 3000 Bq/m³ is based on the Occupational Dose Limit: five year average. An equilibrium factor of 0.4 for Radon-222 and its progeny and 2000 hours per year occupational exposure duration are assumed (Reference 4).
 - 800 Bq/m³ is based on the Radiation Protection Management DWL. An equilibrium factor of 0.4 for Radon-222 and its progeny and 2000 hours per year occupational exposure duration are assumed (Reference 4).
 - 200 Bq/m³ is based on the Investigation DWL. An equilibrium factor of 0.4 for Radon-222 and its progeny and 2000 hours per year occupational exposure duration are assumed (Reference 4).

4.3.2 Public ALIs

Instead of specifying ALI values for public dose, the *Guidelines* present DRLs which specify the maximum total NORM radioactivity (Bq) and radioactive NORM concentration values (Bq/g; Bq/L; Bq/m³) for unconditional releases into the public domain in Tables 5.1, 5.2 and 5.3. This is a more practical method of providing NORM material management guidance and is consistent with other related environmental release standards.

These release limits are based on the dose arising from all the radiation exposure pathways arising from the release, and are based on a maximum annual dose limit of 0.3 mSv as recommended by ICRP 77⁽⁷⁾.

4.3.3 Inhalation Control Measures

Inhalation can deliver most of the dose in some NORM work environments. Where annual intakes exceed 1/20 of the ALI, engineering control of the source of airborne radioactive material is the preferred management method. Controls include capture ventilation at the source to prevent escape into the air, and room ventilation rate increase.

If intakes exceed 25% of the ALI (equivalent to 5 mSv/a) after engineering controls are applied, a respiratory protection program and/or limiting worker access should be considered as part of the radiation protection program. Respiratory protection must follow the standards requirements specified for other hazardous dusts under the local jurisdiction.

Respirator Program

A high protection factor can only be obtained if there is an effective respirator selection, service and fitting program.⁽¹¹⁾

Table 4.2
Annual Limits on Intake for Occupationally Exposed Workers

NORM Radionuclide	Inhalation (5 μ m AMAD) ^(a)			Ingestion		
	Type ^(b)	DC _w (Sv/Bq)	ALI (Bq) ^(c)	f ₁ ^(d)	DC _w (Sv/Bq)	ALI (Bq) ^(c)
Lead-210	F	1.1e-06	18,000	0.2	6.8e-07	29,000
Polonium-210	F	7.1e-07	28,000	0.1	2.4e-07	83,000
	M	2.2e-06	9,000			
Radium-226	M	2.2e-06 ^(g)	9,000	0.2	2.8e-07	71,000
Radium-228	M	1.7e-06	12,000	0.2	6.7e-07	30,000
Thorium-228	M	2.3e-05	900	0.0005	7.0e-08	290,000
	S	3.2e-05	600	0.0002	3.5e-08	570,000
Thorium-232	M	2.9e-05	700	0.0005	2.2e-07	91,000
	S	1.2e-05	1,700	0.0002	9.2e-08	200,000
Uranium ^(e) (all progeny)	Mixed	7.1e-06	2,800	Composite	1.2e-07	170,000
Uranium (par) (U-238, U-234) ^(f)	F	5.8e-07	34,000	0.02	4.4e-08	450,000
	M	1.6e-06	13,000	0.002	7.6e-09	2,600,000
	S	5.7e-06	3,500			

Notes:

- (a) Activity Mean Aerodynamic Diameter. An average inhaled aerosol size of 5 microns (5 μ m).
- (b) The column "Type" reflects the relative rate of absorption of deposited material from the respiratory tract into the blood stream hence the probability of uptake of the material into biological systems. Types F, M, and S materials respectively have; Fast, Moderate and Slow rates of absorption into blood from the respiratory tract.
- (c) ALI values are based solely on radiological considerations where the intake of 1 ALI corresponds to an annual effective dose of 20 mSv. For incidentally exposed workers multiply the ALI values by 1/20. For some long-lived NORM radionuclides, chemical toxicity may be more restrictive. Chemical and radiological toxicity should be reviewed prior to setting workplace exposure limits.

- (d) The retained fraction of the initial intake. The fraction absorbed versus total intake quantity. The rest passes through the GI Tract and is excreted.
- (e) From "Interim Annual Limits on Intake for Long-lived Radioactive Dust", Atomic Energy Control Board (CNSC), January 1995.
- (f) The residual uranium nuclide remaining after the chemical or physical separation of its progeny.
- (g) From "Annex B. Inhalation Dose Coefficients for Workers Exposed to Ra 226", ICRP 72, 1996.

5 NORM Material Management

5.1 Non-radioactive Hazards of NORM Materials

The *Guidelines* provide recommendations based on the radiological properties of NORM. In determining an acceptable material management option, other hazardous properties such as chemical toxicity must be considered. In many cases, the non-radiological hazardous properties of NORM materials are the critical selection criteria for the preferred NORM material management option.

5.2 NORM Derived Release Limits

To assist in NORM material management, Derived Release Limits (DRLs) have been determined from the annual radiation dose limits. The DRLs provide an estimate of public dose from measured releases of NORM. A Radiation Assessment or Material Management program may compare measurement results to DRLs.

5.2.1 Unrestricted Classification

The control of public exposure to radiation from NORM disposal is constrained to less than the public dose limit to allow for exposures from multiple sources. The *Guidelines* recommend that NORM may be released with no radiological restrictions when the associated dose is no more than 0.3 mSv in a year. The radioactive hazard associated with this dose is considered insignificant, and no further control on the material is necessary on radiological protection grounds. It may be necessary to consult and obtain approval from Provincial waste disposal regulatory agencies regarding non-radiological properties.

DRLs for the amount and concentration of NORM materials that meet this criteria have been calculated, and are presented in Tables 5.1, 5.2 and 5.3 as Unconditional Derived Release Limits (UDRLs).

5.2.2 Release with Conditions

NORM quantities in excess of the UDRLs may, after a specific site review, be released without further consideration. In such instances, the basic premise is that the material, in its final disposition, will not contribute a dose to an individual that is greater than 0.3 mSv/a. Outside those situations or conditions, the material falls within a more restrictive NORM classification.

5.3 Derived Release Limits for NORM Materials

5.3.1 Diffuse NORM

Diffuse NORM is generally large in volume, with a relatively low radioactive concentration that is uniformly dispersed throughout the material. Diffuse NORM by-products from industrial activity are usually stored close to the point of generation as the cost of long distance transportation is prohibitive. Phosphogypsum, a by-product of fertilizer production, is an example of diffuse NORM.

Disposal of diffuse NORM sources requires consideration of the effects of dilution, possible re-concentration of the material in the environment, and the manner in which the material may deliver radiation doses to the public.

Table 5.1 shows the UDRLs for Diffuse NORM. Unrestricted release of NORM at the listed concentrations will deliver a maximum effective dose of 0.3 mSv/a under conservative scenarios. The calculations are given in Appendix E. Actual effective doses arising from releases of NORM at UDRLs are expected to be substantially less than the 0.3 mSv/a.

**Table 5.1
Unconditional Derived Release Limits- Diffuse NORM Sources**

NORM Radionuclide	Derived Release Limit ^(a)		
	Aqueous ^(b) (Bq/L)	Solid (Bq/kg)	Air (Bq/m ³)
Uranium-238 Series (all progeny)	1	300	0.003
Uranium-238 (U-238, Th-234, Pa-234m, U-234)	10	10,000	0.05
Thorium-230	5	10,000	0.01
Radium-226 (in equilibrium with its progeny)	5	300	0.05
Lead-210 (in equilibrium with bismuth-210 and polonium-210)	1	300	0.05
Thorium-232 Series (all progeny)	1	300	0.002
Thorium-232	1	10,000	0.006
Radium-228 (in equilibrium with Ac-228)	5	300	0.005
Thorium-228 (in equilibrium with all its progeny)	1	300	0.003
Potassium-40	n/a ^(d)	17,000 ^(c)	n/a

Notes:

(a) Pathways Considered:

Aquatic

1. Value 10x Guideline for Canadian Drinking Water Quality.

Terrestrial

1. External groundshine from soil contaminated to infinite depth.
2. Soil-veg-ingestion/soil ingestion.
3. Inhalation of resuspended material.

Air

1. Inhalation at concentration resulting in 0.3 mSv.
2. Exposure factor of 25% assumed.

Assumptions:

- All radionuclides and compartments in equilibrium.
- Typical values for uptake and transfer factors.
- No allowance for hold-up time.
- 25% “occupancy” factor for solid source (groundshine, soil ingestion, resuspension), 25% ‘occupancy’ factor for air, and 50% of vegetable intake grown on soil.
- No correction for shielding, surface roughness.

Where more than one long-lived radionuclide is present in a sample, the appropriate sum of the ratios of the activity of each long-lived radionuclide and its corresponding Release limit, must not exceed 1, for example:

$$\frac{\text{Concentration NORM Isotope A}}{\text{Derived Release Limit A}} + \frac{\text{Concentration NORM Isotope B}}{\text{Derived Release Limit B}} + \dots + \frac{\text{Concentration NORM Isotope N}}{\text{Derived Release Limit N}} \leq 1$$

- (b) Aqueous Release limits ~10x Guidelines for Canadian Drinking Water Quality. Subsequent dilution of the release is assumed. Refer to the Provincial Drinking Water Standard where planned diffuse NORM releases must meet provincial drinking water standards. (See reference 15)
- (c) Natural abundance of Potassium 40 in potassium chloride.
- (d) No aqueous release limit is needed as potassium content of the body is under homeostatic control, and is not influenced by environmental levels.

5.3.2 Discrete NORM

Discrete NORM sources are small in size and exceed the concentration criteria for a diffuse source. Because of the possibility of high radiation dose-rates close to the source, the UDRLs are lower than for diffuse NORM.

Table 5.2 lists the UDRLs for discrete NORM sources. The material must also meet the applicable radioactive surface contamination values, shown in Table 5.3.

**Table 5.2
Unconditional Derived Release Limits**

NORM Radionuclide	Unconditional Derived Release Limit^(a) (Bq)
Uranium Ore (in equilibrium with all progeny)	1,000
Uranium-238 (partitioned) (in equilibrium with thorium-234 and protactinium-234)	10,000
Thorium-230 (no progeny)	10,000
Radium-226 (in equilibrium with its progeny)	10,000
Lead-210 (in equilibrium with bismuth-210 and polonium-210)	10,000
Thorium-232 (in equilibrium with all progeny)	1,000
Radium-228 (in equilibrium with actinium-228)	100,000
Thorium-228 (in equilibrium with its short-lived progeny)	10,000
Potassium-40	1,000,000

Notes:

- (a) UDRLs, DRLs, (Activity and Concentration) relate to the long-lived parent radionuclide in equilibrium with its progeny. The use of Uranium Ore is considered appropriate for NORM-contaminated substances where equilibrium has not been disturbed by partitioning of the Uranium decay series. Where partitioning has occurred, the activity of *each* long-lived radionuclide must be found and compared to its appropriate UDRL. Where more than one long-lived radionuclide is present in a sample, the appropriate sum of the ratios of the activity of each long-lived radionuclide and its corresponding UDRL, must not exceed 1, for example:

$$\frac{\text{Activity NORM Isotope A}}{\text{Unconditional DRL A}} + \frac{\text{Activity NORM Isotope B}}{\text{Unconditional DRL B}} + \dots + \frac{\text{Activity NORM Isotope N}}{\text{Unconditional DRL N}} \leq 1$$

5.3.3 Surface Contamination

Limits for surface radioactive contamination on equipment, tools or scrap surfaces intended for unconditional release are based on the analysis of personal radiation exposure pathways to a maximum annual dose of 0.3 mSv. Discrete NORM sources with surface contamination less than the Table 5.3 Surface Contamination Unconditional Derived Release Limits can be released without further investigation.

Table 5.3
Surface Contamination Unconditional Derived Release Limits - Discrete NORM
Sources

Property	Limit
Dose Rate	0.5 $\mu\text{Sv/h}$ at 50 cm.
Surface Contamination	1 Bq/cm^2 averaged over a 100 cm^2 area

Notes:

1. A thin window radiation detector is recommended when monitoring beta/gamma sources of surface contamination.
2. Table 5.3 release limits are only applicable to fixed surface contamination. Loose surface contamination must be completely removed or all accessible surfaces stripped to ensure complete removal.
3. In most cases, decontamination efforts which meet beta surface contamination limits will concurrently provide for the control of mixed alpha / beta / gamma sources.

6 Standards for the Transport of NORM

Shipments of NORM may fall under federal transportation regulations, the *Packaging and Transport of Nuclear Substances Regulations* (PTNSR) and the *Transportation of Dangerous Goods Regulations* (TDGR). The TDGR outlines the responsibilities of the consignor, consignee and transporter and the PTNSR, which have been harmonized with the IAEA's Safety Standard No. TS-R-1 Regulations for the Safe Transport of Radioactive Materials, 1996 (revised)⁽¹⁴⁾, outline the packaging, labeling and manifesting requirements for a NORM shipment. Shipments of NORM fall under these regulations if:

- the activity concentration of the material exceeds 10 times the "activity concentration for an exempt material" values specified in Table 6.1; and
- the material is transported off site over public or privately owned land not controlled by the consignment owner.

Prior to shipment, the NORM material must be assessed to determine the activity concentration.

Tables 6.1 and 6.2 outline the IAEA Safety Standards Series No. TS-R-1 Basic Radionuclide Values for NORM as well as Parent nuclides and their progeny included in secular equilibrium. The original document should be referenced for full definitions and context of use. TS-R-1 is available for download from the IAEA website at http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1098_scr.pdf.

Table 6.1
Basic NORM Radionuclide Values, paragraph 404, IAEA Safety Standards Series
No. TS-R-1

Definitions⁽¹⁴⁾ of A₁ and A₂:

A₁ shall mean the activity value of *special form radioactive material* which is used to determine the activity limits. A₂ shall mean the activity value of *radioactive material*, other than *special form radioactive material*, which is used to determine the activity limits.

Radionuclide	A ₁ (GBq)	A ₂ (GBq)	Activity concentration for exempt material (Bq/g)	Activity limit for an exempt consignment (Bq)
U-(nat)	Unlimited	Unlimited	1**	1,000**
U-238 (all lung absorption types)	Unlimited	Unlimited	10**	10,000**
Th-234*	300	300	1000**	100,000**
U-234 (slow lung absorption)	40,000	6	10	100,000
Th-230	10,000	1	1	10,000
Ra-226*	200	3	10**	10,000**
Pb-210*	1000	50	10**	10,000**
Th(nat)	Unlimited	Unlimited	1**	1,000**
Th-232	Unlimited	Unlimited	10	10,000
Ra-228*	600	20	10	100,000**
Th-228*	500	1	1	10,000**

* A₁ and/or A₂ values include contributions from progeny with half-lives < 10 days

** See progeny included in value. They are as follows in Table 6.2.

Note: For NORM materials these values are multiplied by 10 (naturally occurring).

Table 6.2
Parent nuclides and their progeny included in secular equilibrium

Parent Radionuclide	Progeny
Bi-212	Tl-208 (0.36), Po-212 (0.64)
Pb-210	Bi-210, Po-210
Pb-212	Bi-212, Tl-208(0.36), Po-212(0.64)
Ra-226	Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210, Po-210
Ra-228	Ac-228
Th-228	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208(0.36), Po-212(0.64)
Th-nat	Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208(0.36), Po-212 (0.64)
Th-234	Pa-234m
U-230	Th-226, Ra-222, Rn-218, Po-214
U-232	Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212(0.64)
U-238	Th-234, Pa-234m
U-nat	Th-234, Pa-234m, U-234, Th-230, Ra-226, Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210, Po-210

6.1 Unrestricted NORM Shipments

Materials meeting all of the following criteria do not require any special considerations for transportation:

- **Meets** the CNSC exemption criteria under the PTNSR. NORM that is in its natural state or NORM that has been processed only for purposes other than for extraction of those radionuclides provided the activity concentration of the material does not exceed 10 times the "activity concentration for an exempt material" values specified in Table 6.1, and
- **Meets** the UDRLs of section 5.3 of these guidelines.

6.2 NORM Shipments Subject to the Canadian Guidelines

For NORM shipments having an activity concentration less than 10 times the value in Table 6.1 but greater than the UDRLs in Section 5.3, the following are recommended:

- A transport manifest is completed and contains the descriptor "*Naturally Occurring Radioactive Material – NORM*".

- The shipment is securely packaged in a manner that effectively prevents release or redistribution of any NORM contamination during transport.
- The shipment has taken into account any other potential hazardous properties of the materials.

NOTE: no radioactive placards or labels should be affixed to the transport vehicle or to the exterior surfaces of the packaging.

6.3 NORM Shipments governed by the Federal Transport Regulations

Shipments of NORM falling under federal jurisdiction are required to comply with the PTNSR, established by the CNSC.

Preparation of these shipments for transport involves several steps. As a result, lead times four to six weeks prior to shipment should be planned. Timely transportation of NORM to a secure central site is recommended. For more information concerning transportation requirements, contact the appropriate Federal, Provincial or Territorial government agency. A list of government contacts is provided in Appendix B.

6.4 NORM Surface Contamination Exclusions

A surface contaminated object (SCO) is a solid object which is not itself radioactive but which has radioactive material distributed on its surface. An object with external contamination is exempted from the PTNSR if:

- (a) the non-fixed contamination when averaged over each 300 cm² of all surfaces is less than 0.4 Bq/cm² for beta and gamma emitters and low toxicity alpha emitters*, and is less than 0.04 Bq/cm² for all other alpha emitters; and
- (b) the activity concentration of the material does not exceed 10 times the activity concentration for an exempt material as specified in Table 6.1.

* Low toxicity alpha emitters are: natural uranium, depleted uranium, uranium-235 or uranium-238, thorium 232, thorium -228 and thorium-230 when contained in ores or physical and chemical concentrates, or alpha emitters with a half life less than 10 days.

6.5 Additional Information

Refer to the PTNSR, the TDGR, and the IAEA Regulations for the Safety Transport of Dangerous Goods for additional information on requirements for the transport of NORM ^(12, 13, 14).

References

- 1 *Guidelines for The Handling of Naturally Occurring Radioactive Materials (NORM) In Western Canada*, Western Canadian NORM Committee, Aug. 1995.
- 2 *Canada: Living With Radiation*, Atomic Energy Control Board, Canada Communication Group-Publishing, 1995.
- 3 *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Annals of the ICRP, Vol. 21, No. 1-3, 1991.
- 4 *Protection Against Radon-222 at Home and at Work*, ICRP Publication 65, Annals of the ICRP, Vol. 23, No. 2, 1993.
- 5 *1994 Dose Coefficients for Intake of Radionuclides by Workers*, ICRP Publication 68, Annals of the ICRP, Vol. 24, No. 4, 1994.
- 6 *Age Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 - Compilation of Ingestion and Inhalation Coefficients*, ICRP Publication 72, Annals of the ICRP, Vol. 26, No. 1, 1996.
- 7 *Radiological Protection Policy for the Disposal of Radioactive Waste*. ICRP Publication 77, Annals of the ICRP, Vol. 27, Supplement 1997.
- 8 *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources*, IAEA Safety Series No. 115, 1996.
- 9 *Technical and Quality Assurance Requirements for Dosimetry Services*, S-106 Revision 1, Published by the Canadian Nuclear Safety Commission, May 2006.
- 10 *Radon – Reduction Guide for Canadians*, Health Canada, 2013. http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radon_canadians-canadiens/index-eng.php
- 11 *Selection, Care and Use of Respirators*, Canadian Standards Association, Z94.4- 93, August 1994.
- 12 *Packaging and Transport of Nuclear Substances Regulations*, Nuclear Safety and Control Act, May 2000, available at www.nuclearsafety.gc.ca
- 13 *Transportation of Dangerous Goods Regulations*, Canada Gazette Part II, February 20, 2008, available for download from the Transport Canada website at <http://www.tc.gc.ca/>
- 14 *Regulations for the Safe Transport of Radioactive Material*, 1996 Edition (Revised), Safety Standards Series No. TS-R-1 (ST-1, Revised), International Atomic Energy Agency, available at www.iaea.org.
- 15 *Guidelines for Canadian Drinking Water Quality*, Health Canada, December 2010.

- 16 Revised Canadian Guidelines for Radon, Canada Gazette Part I, Vol. 141, No. 23, June 9, 2007.
- 17 *The 2007 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103, Annals of the ICRP, Vol. 37, No. 2-4, 2007.
- 18 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Effects of ionizing radiation. Volume I: Annex E - Sources-to-effects assessment for radon in homes and workplaces. ISBN 978-92-1-142263-4. United Nations, New York 2006

A Appendix

Publications Address List

Canadian Nuclear Safety Commission

Office of Public Information
Canadian Nuclear Safety Commission
280 Slater Street, P.O. Box 1046
Ottawa, Ontario K1P 5S9

Health Canada

Radiation Protection Bureau, AL 6302A
775 Brookfield Road
Ottawa, Ontario, K1A 1C1

International Atomic Energy Agency (IAEA)

IAEA Regional Office in Canada
Suite 1702/Box 20
365 Bloor Street East
Toronto, ON M4W 3L4

Bernan Associates
4611-F Assembly Drive
Lanham MD. USA 20706-4391

Division of Publications
International Atomic Energy Agency
Wagramerstrasse 5, P.O. Box 100
A-1400 Vienna, Austria

International Commission on Radiological Protection (ICRP)

Pergamon Press Inc.
Maxwell House, Fairview Park
Elmsford, New York, U.S.A.

Pergamon Press plc,
Headington Hill Hall
Oxford, U.K. OX3 0BW

Guidelines for the Handling of Naturally Occurring Radioactive Materials (NORM) in Western Canada

Alberta Human Resources and Employment
Information Services
2nd Floor, 10808 - 99 Avenue

Edmonton, Alberta, Canada T5K 0G5

B Appendix

Government Contacts

Federal Government Agencies

Canadian Nuclear Safety Commission

P.O. Box 1046
Ottawa, Ontario K1P 5S9
1-800-668-5284 or (613) 992-2915

Health Canada

Radiation Protection Bureau
775 Brookfield Road,
Ottawa, Ontario K1A 1C1
(613) 954-6647

Health Canada

National Dose Registry
Radiation Protection Bureau
775 Brookfield Road,
Ottawa, Ontario K1A 1C1
ndr-fdn@hc-sc.gc.ca

Provincial Government Agencies

Alberta

Occupational Health and Safety
Alberta Human Services
8th Floor, 10808- 99 Avenue
Edmonton, Alberta T5K 0G5
(780) 427-2687

British Columbia

Environmental Assessment Office (EAO)BC Ministry of Environment
PO Box 9426 Stn Prov Govt
Victoria, British Columbia V8W 9V1
(250) 356-6448

Manitoba

Radiation Protection Section
Manitoba Cancer Treatment and Research Foundation
100 Olivia Street
Winnipeg, Manitoba R3E 0V9
(204) 787-2213

New Brunswick

Public Health Management Unit
Health and Community Services
P.O. Box 5100
Fredericton, New Brunswick E3B 5G8
(506) 453 2638

Newfoundland

Employment and Labour Relations
Fall River Plaza, P.O. Box 8700
270 Torbay Road,
St. John's, Newfoundland A1C 4J6
(709) 729-0218

Northwest Territories

Department of Health and Social Services
Government of the Northwest Territories
7th Floor, Centre Square Tower
P.O. Box 320
Yellowknife, Northwest Territories X1A 2L9
(867) 920-3293

Nova Scotia

Department of Labour and Workforce Development
P.O. Box 697
Halifax, Nova Scotia B3J 3B7
(902) 424-7115

Nunavut Territory

Department of Health and Social Services
Government of the Northwest Territories
7th Floor, Centre Square Tower
P.O. Box 320
Yellowknife, Northwest Territories X1A 2L9
(867) 920-3293

Ontario

Ontario Ministry of Labour
Radiation Protection Service
81A Resources Road
Toronto, Ontario M9P 3T1
(416) 235-5922

Prince Edward Island

Division of Environmental Health
Department of Health and Social Services
Government of Prince Edward Island
P.O. Box 2000
Charlottetown, P.E. I. C1A 7N8
(902) 894-2277

Quebec

Service de la Promotion de saines habitudes de vie et de dépistage
Ministère de la Santé et des Services sociaux
1075, chemin Ste-Foy
Québec, Québec G1S 2M1
(418) 646-2515

Saskatchewan

Radiation Safety Unit
Occupational Health and Safety Division
Saskatchewan Ministry of Labour Relations and Workplace Safety
1870 Albert Street
Regina, Saskatchewan S4P 4W1
(306) 787-4538

Yukon Territory

Workers Compensation Health & Safety
Government of the Yukon Territory
401 Strickland Street
Whitehorse, Yukon Territory Y1A 5N8
(780) 667-5450

C Appendix

Radiation Unit Conversion Factors

Table C.1 Prefixes

Prefix	Symbol	Value
Tera	T	10^{12}
Giga	G	10^9
Mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Table C.2 Activity Conversions

Activity (SI Units)		Activity (Former Units)	
Becquerel (Bq)	Disintegration per second (dps)	Curie with prefix (Ci)	Curie (Ci)
1 Bq	1 dps	27 pCi	2.7×10^{-11} Ci
1 kBq	1×10^3 dps	27 nCi	2.7×10^{-8} Ci
1 MBq	1×10^6 dps	27 μ Ci	2.7×10^{-5} Ci
1 GBq	1×10^9 dps	27 mCi	2.7×10^{-2} Ci
1 TBq	1×10^{12} dps	27 Ci	2.7×10 Ci
37 mBq	0.037 dps	1 pCi	1×10^{-12} Ci
37 Bq	37 dps	1 nCi	1×10^{-9} Ci
37 kBq	3.7×10^4 dps	1 μ Ci	1×10^{-6} Ci
37 MBq	3.7×10^7 dps	1 mCi	1×10^{-3} Ci
37 GBq	3.7×10^{10} dps	1 Ci	1 Ci

Table C.3 Absorbed Dose Conversions

SI Units	Former Units
1 Gy	100 rad
1 mGy	0.1 rad
1 μ Gy	0.1 mrad
10 mGy	1 rad
10 μ Gy	1 mrad
0.01 μ Gy	1 μ rad

Table C.4 Dose Equivalent “Biological Dose” Conversions

SI Units	Former Units
1 Sv	100 rem
1 mSv	0.1 rem
1 μ Sv	0.1 mrem
10 mSv	1 rem
10 μ Sv	1 mrem
0.01 μ Sv	1 μ rem

Table C.5 Radon Conversions

Radiation Exposure Domain	Radon Gas (Bq/m^3)	Radon Progeny (WLM)	Radon Progeny (mJ h/m^3)	Annual Radiation Dose (mSv/a)
Occupational (2000 hours per year)	200	0.25	0.89	1.4

D Appendix

Effective Dose Calculations

1. Effective Dose Categories

The total Effective Dose, E_T , is calculated from three categories of radiation exposure:

a. External gamma and beta dose

This dose category, personal dose equivalent from penetrating radiation, is symbolized by “ $H_p(10)$ ” and represents the beta/gamma dose received in a dosimetry period. A one-year dosimetry period is defined as the dosimetry period commencing January 1 and having one calendar year duration. The five-year dosimetry period means the period of five calendar years beginning January 1 of the year after these guidelines are published, and every period of five calendar years thereafter.

b. Internal dose from the intake of radionuclides

This dose category is symbolized by “ I ” and represents the one-year or five-year dosimetry period estimate of NORM nuclide intake (inhalation and ingestion) other than from radon and its progeny.

c. Inhalation of radon gas and its progeny

This dose category is defined by cumulative exposure to radon progeny symbolized by “ RnP ” with units of WLM. RnP represents the one-year or five-year dosimetry period estimate of cumulative radon progeny inhalation by workers.

For dose recording purposes, each dose category can be measured and recorded separately. For compliance to these *Guidelines*, or, federal, provincial or territorial dose limit regulations, these categories must be combined to calculate one effective dose for each individual. This combined dose, the effective dose, is then compared to the radiation dose limits found in Table 2.1 of the *Guideline*.

2. Effective Dose and Dose Limit Compliance Calculations

For worker dose compliance purposes, the *Guidelines* require dose calculations over a one-year and a five-year dosimetry period. One-year dosimetry period calculations are necessary for compliance with one-year maximum effective dose limits, while five-year dosimetry period calculations demonstrate compliance with the cumulative dose limits for a five-year period. The five-year cumulative limit also implies an average annual dose limit.

For workers, the implied average annual limit over a five-year period is an annual effective dose of 20 mSv versus the 50 mSv maximum in any single one-year dosimetry period. For the public, including the incidentally exposed worker, the annual limit is 1 mSv and the five-year limit is five times the annual limit. The following dose calculation methodology is recommended for determining one-year and five-year dosimetry period results.

A. One Year Dosimetry Periods

Step 1

Calculate the annual dose received from each dose category.

External Gamma and Beta Exposures

Annual dose received from all external sources, $H_p(10)$

Radionuclide Intake (Internal Exposures)

Annual dose received from all internal sources,

$$I = \sum A_n \times DC_{wn}$$

Where, A_n is the activity intake of radionuclide n and DC_{wn} is the appropriate worker dose coefficient specified for that NORM nuclide (Refer to Table 4.1 entries). For inhalation, the DC_{wn} selected from Table 4.1 will depend on the chemical form of the radionuclide, which will determine whether it is fast (F), moderate (M) or slow (S) absorption from the lungs.

Radon-222 Inhalation

Annual dose received from radon-222 progeny inhalation,

$$Rn_d = 5(RnP)$$

Where, for workers the dose conversion from WLM to mSv is 5 for radon-222 progeny. Radon-220 progeny must be treated separately.

Step 2. One-Year Dosimetry Period Compliance

Determine the effective dose by adding the dose contributions from the three categories. To determine whether the annual total effective dose received complies with the *Guidelines* compare it to the appropriate one-year dose limit from Table 2.1.

Compliance: $E_T = H_p(10) + I + Rn_d \leq \text{the appropriate value from Table 2.1}$

Example 1: During the year, a worker has been exposed to external gamma radiation, has ingested radium dust and was exposed to radon-222 progeny. The workers recorded doses/intakes are presented in Table D.1.

Table D.1
Worker's Record of Doses and Intakes for Example 1

Source	Recorded Dose/Intake	Effective Dose
External Radiation $H_p(10)$	12 mSv	$H_p(10) = 12 \text{ mSv}$
Internal Radiation (radium-226) I_n	9,000 Bq	$I = 2.5 \text{ mSv}$
Radon Rn_d	0.4 WLM	$Rn_d = 2 \text{ mSv}$

This worker's internal dose component (I) can be calculated using Table 4.1. The ingestion DC_w for ^{226}Ra is $2.8 \text{ e-}7 \text{ Sv/Bq}$.

$$\text{Therefore } I = (9,000 \text{ Bq})(2.8 \text{ e-}7 \text{ Sv/Bq}) = 0.0025 \text{ Sv} = 2.5 \text{ mSv}$$

This worker's radon dose component (Rn_d) can be calculated by multiplying the dose in WLM by 5 to convert to mSv.

$$\text{Therefore } Rn_d = (0.4 \text{ WLM})(5 \text{ mSv/WLM}) = 2 \text{ mSv}$$

$$\begin{aligned} \text{Effective Dose: } E_T &= H_p(10) + I + Rn_d \\ &= 12 \text{ mSv} + 2.5 \text{ mSv} + 2 \text{ mSv} \\ &= 16.5 \text{ mSv} \end{aligned}$$

Conclusion: The worker has not exceeded the annual dose limit of 50 mSv. However the worker is getting close to the average annual dose limit implied by the five-year limit (20 mSv/a).

B. Five-year Dosimetry Period

Step 1

Calculate the dose received in the five year period, or portion thereof, from each dose category.

External Gamma and Beta Exposures

Total dose received during the five year period, or portion thereof, from all external sources = $H_p(10)$

Radionuclide Intake (Internal Exposures)

Total dose received during the five year period, or portion thereof, from all internal sources,

$$I = \sum A_n \times DC_{wn}$$

Where, A_n is the activity intake of radionuclide n and DC_{wn} is the worker dose coefficient specified for that NORM nuclide (Refer to Table 4.1 entries). For inhalation, the DC_{wn} selected from Table 4.1 will depend on the chemical form of the radionuclide, which will determine whether it is fast (F), moderate (M) or slow (S) absorption from the lungs.

Radon-222 Inhalation

Total dose received during five year period, or portion thereof, from radon-222 progeny inhalation,

$$Rn_d = 5(RnP)$$

Where, for workers the dose conversion from WLM to mSv is 5. Radon-222 progeny must be treated separately.

Step 2. Five Year Dose Limit Compliance

Determine the effective dose by adding the dose contributions from the three categories. To determine whether the effective dose received complies with the *Guidelines* compare it to the appropriate five-year dose limit from Table 2.1.

Compliance: $E_T = H_p(10) + I + Rn_d \leq \text{the appropriate value from Table 2.1}$

Example 2: During a five-year period, a worker has been exposed to external gamma radiation, has ingested radium in dust and was exposed to radon-222 progeny. The workers recorded doses/intakes are presented in Table D.2.

Table D.2
Worker's Record of Doses and Intakes for Example 2

Source	Recorded Dose/Intake	Effective Dose
External Radiation $H_p(10)$	30 mSv	$H_p(10) = 30 \text{ mSv}$
Internal Radiation (radium-226) I_n	26,000 Bq	$I = 7.3 \text{ mSv}$
Radon RnP	1 WLM	$Rn_d = 5 \text{ mSv}$

This worker's internal dose component (I) can be calculated using Table 4.1. The DC_w for ^{226}Ra is $2.8 \text{ e-}7 \text{ Sv/Bq}$.

$$\text{Therefore } I = (26,000 \text{ Bq})(2.8 \text{ e} - 7 \text{ Sv/Bq}) = 0.073 \text{ Sv} = 7.3 \text{ mSv}$$

This worker's radon dose component (Rn_d) can be calculated by multiplying the dose in WLM by 5 to convert to mSv.

$$\text{Therefore } Rn_d = (1 \text{ WLM})(5 \text{ mSv/WLM}) = 5 \text{ mSv}$$

Effective Dose:
$$\begin{aligned} E_T &= H_p(10) + I + Rn_d \\ &= 30 \text{ mSv} + 7.3 \text{ mSv} + 5 \text{ mSv} \\ &= 42.3 \text{ mSv} \end{aligned}$$

Conclusion: The worker has not exceeded the five-year dose limit of 100 mSv.

E Appendix

Derivation of Diffuse NORM Unconditional Derived Release Limits

The Unconditional Derived Release Limit for diffuse NORM sources (solid, air, and water) is the concentration of the parent radionuclide (Bq per unit mass or volume), in equilibrium with its progeny, that could result in a dose of 0.3 mSv per year from those pathways considered in the assessment, based on conservative exposure assumptions (conservative assumptions are those that are least likely to understate exposure). The pathways, assumptions, and other related information are supplied below for the calculation of the limits for the decay chains listed in Table 5.1.

Unconditional Derived Release Limits have been calculated for ^{40}K , and for the ^{238}U and ^{232}Th decay series. Values for the two decay series are given for the various sub-chains that can be assumed to be in equilibrium, in other words, the parent radionuclide is in equilibrium with its shorter-lived progeny. For example, within the ^{238}U series, a release limit is given for ^{210}Pb in equilibrium with its progeny, ^{210}Bi and ^{210}Po .

Exposure Pathways for Diffuse NORM Sources

Solid NORM

For diffuse solid NORM, the release limit is the concentration in soil (Bq/kg) *at the receptor* that would result in a dose of 0.3 mSv/a to a reference adult. Based on a modification to the screening methodology recommended by the National Commission for Radiation Protection (NCRP) for disposal of radionuclides in the ground (NCRP 1996), it is assumed that the radioactive material is uniformly distributed in soil to infinite depth, and that the reference individual resides on this soil and consumes produce grown on the soil. The following exposure pathways and assumptions were considered:

- The parent radionuclide and its progeny are in equilibrium.
- The reference adult is exposed to direct external irradiation from the soil, which is assumed to be homogeneously contaminated to infinite depth.
- The individual receives an internal dose from the inhalation of resuspended dust, contaminated to the same level as the soil.
- Half of the individual's annual supply of vegetables is grown on contaminated soil. It is assumed that the land does not support livestock, so there is no dose from the consumption of animal products.
- The individual ingests contaminated soil from unwashed produce, dirt on hands, etc.
- The reference individual is assumed to occupy the site for 25% of the year, affecting the direct irradiation, inhalation, and soil ingestion pathways.

Airborne NORM

For airborne NORM, the unconditional release limit is the concentration in air (Bq/m^3) **at the receptor** that would result in a dose of 0.3 mSv/a to a reference adult from inhalation. The following assumptions apply:

- Only the inhalation pathway is assumed.
- The parent radionuclide and its progeny are in equilibrium (very conservative).
- The reference individual is assumed to occupy the site for 25% of the year.

Aquatic NORM

For aquatic NORM, the Unconditional Derived Release Limit is the concentration in water (Bq/L) **at the point of release** that would result in a dose of less than 0.3 mSv/a to a reference adult consuming water for an entire year assuming a four to ten-fold dilution in concentration between the NORM release point and a drinking water intake point. Equilibrium between the parent and its progeny is not assumed. The release limit is therefore 10 times the maximum acceptable concentration given in the Guidelines for Canadian Drinking Water Quality, 6th edition (Health Canada 1996), which is based on a dose of 0.1 mSv/a. Regardless of the NORM guideline, in all cases, provincial drinking water standards would apply to the water as released.

Discussion of Parameters Used in the Derivation of Unconditional Release Limits

Soil to plant uptake factors, Bv_x , for the various radionuclides of interest are taken from Zach and Sheppard (1992), Table 6. These were selected by Zach and Sheppard, based on a review of available data, as being appropriate mean values for the Canadian Shield.

Annual adult consumption rates for vegetables and soil are taken from Health Canada (1993). A factor of 0.5 has been applied to the intake of produce to reflect the assumption that one-half of the annual intake is grown on contaminated soil. The adult water consumption rate is from Health Canada (1996). The inhalation rate is from ICRP Publication 71 (1995), Table 6. Soil density (for conversion of groundshine dose coefficients) is taken from CSA (1987). The soil resuspension factor is from Davis *et al* (1993). An occupancy correction factor of 0.25 has been applied to exposure to airborne NORM sources by inhalation, and to exposures to solid NORM sources by

- direct groundshine irradiation;
- ingestion of soil; and
- inhalation of resuspended dust.

Committed effective dose coefficients for internal exposure (inhalation, ingestion) are from ICRP Publication 72 (1996). External dose rate coefficients for soil contaminated to infinite depth are taken from Eckerman and Legett (1996); Eckerman and Ryman (1993). These are consistent with ICRP 60 methodologies. Parameters values used in the calculation of unconditional release limits are summarised in Table 1.

It is assumed that:

- All radionuclides in the defined parent-progeny group are in equilibrium for both solid and airborne NORM sources.
- For aquatic NORM, equilibrium is not assumed, and the unconditional release limit is based on each separate radionuclide released.
- All compartments are in equilibrium, and at steady-state.
- No allowance is made for transfer times between compartments, or hold-up time of food (for example between harvest and consumption).
- No corrections are made for reduction in external irradiation due to shielding, surface roughness, etc.

Methodology and Equations:

Solid and Airborne NORM:

For a given decay chain in equilibrium (for example, $^{238}\text{U} \rightarrow ^{234}\text{Th} \rightarrow ^{234\text{m}}\text{Pa}$), the doses resulting from a unit concentration of *each* radionuclide, x , by each relevant exposure pathway, y , referred to as $D_{x,y}$ (mSv y^{-1}) were calculated as follows, where $DC_{x,y}$ is the radionuclide- and pathway-specific effective dose coefficient:

For Solid NORM:

- External groundshine

$$D_{x,ext/gnd} = \text{soil conc'n (Bq/kg)} \times DC_{x,ext/gnd} (\text{Sv m}^3 \text{Bq}^{-1} \text{s}^{-1}) \times \text{soil density (kg m}^{-3}) \times \{3.16 \times 10^7 (\text{s y}^{-1}) \times \text{occupancy factor (0.25)}\} \times 1000 (\text{mSv Sv}^{-1})$$

- Internal, ingestion of vegetables

$$D_{x,ingest/veg} = \text{soil conc'n (Bq/kg)} \times DC_{x,ingest} (\text{Sv Bq}^{-1}) \times \{\text{Plant uptake factor} \times \text{veg. consumption rate (kg y}^{-1}) \times 0.5\} \times 1000 (\text{mSv Sv}^{-1})$$

- Internal, ingestion of soil

$$D_{x,ingest/soil} = \text{soil conc'n (Bq/kg)} \times DC_{x,ingest} (\text{Sv Bq}^{-1}) \times \{\text{soil ingestion rate (kg y}^{-1}) \times \text{occupancy factor (0.25)}\} \times 1000 (\text{mSv Sv}^{-1})$$

- Internal, inhalation of resuspended material

$$D_{x,inhal/resus} = \text{soil conc'n (Bq/kg)} \times DC_{x,inhal} (\text{Sv Bq}^{-1}) \times \text{dust loading factor (kg m}^{-3}) \times \{\text{inhalation rate (m}^3 \text{y}^{-1}) \times \text{occupancy factor (0.25)}\} \times 1000 (\text{mSv Sv}^{-1})$$

Table E.1
Parameter Values

Parameter	Element	Value	Reference
Plant/Soil Uptake, Bv_x (Bq/kg wet / Bq/kg dry)	K	2.5E-01	(Zach and Sheppard, 1992)
	Pb	1.1E-02	
	Bi	8.8E-03	
	Po	6.3E-04	
	Ra	3.3E-03	
	Ac	8.8E-04	
	Th	2.1E-04	
	Pa	6.3E-04	
	U	2.1E-03	
Soil density (kg m^{-3})		1.6E+03	(CSA 1987)
Food consumption: Veg (kg y^{-1})		2.5E+02	(Health Canada 1993)
Soil ingestion rate (kg y^{-1})		7.3E-03	(Health Canada 1993)
Dust loading - resuspension (kg m^{-3})		6.0E-08	(Davis <i>et al.</i> 1993)
Adult breathing rate ($\text{m}^3 \text{y}^{-1}$)		8.1E+03	(ICRP 1995)
Occupancy Factor		2.5E-01	(NCRP 1996)
External dose coefficients ($\text{Sv m}^3 \text{Bq}^{-1} \text{s}^{-1}$)		Note (a)	(Eckerman and Legett 1996)
Internal dose coefficients (Sv Bq^{-1})		Note (a)	(ICRP 1996)

(a) Dose coefficients are radionuclide dependent. Refer to listed references for specific values.

For Airborne NORM:

- Internal, inhalation of airborne material

$$D_{x, \text{inhal/air}} = \text{conc}'n \text{ in air } (\text{Bq m}^{-3}) \times DC_{x, \text{inhal}} (\text{Sv Bq}^{-1}) \times \{\text{inhalation rate } (\text{m}^3 \text{y}^{-1}) \times \text{exposure factor } (0.25)\} \times 1000 (\text{mSv Sv}^{-1})$$

Calculation of the Unconditional Derived Release Limit

The total dose per unit concentration (soil or airborne) is given by a double sum over each radionuclide and pathway:

$$D_{\text{total,soil/air}} (\text{mSv y}^{-1} \text{ per Bq/kg (or m}^{-3}\text{)}) \\ = \sum \sum D_{x,y} \text{ for each radionuclide, } x \text{ in each exposure pathway, } y$$

The Unconditional Derived Release Limit, UDRL, for the parent radionuclide in equilibrium with its progeny is:

$$URL (Bq/kg \text{ (or } m^{-3})) \\ = 0.1 \text{ mSv } y^{-1} / D_{total,soil/air} (\text{mSv } y^{-1} \text{ per } Bq/kg \text{ (or } m^{-3}) \text{ for soil (or airborne)})$$

Aquatic NORM

As discussed above, the unconditional derived release limit for aquatic NORM is 10 times the maximum acceptable concentration given in the Guidelines for Canadian Drinking Water Quality, 6th edition (Health Canada 1996) for the parent radionuclide. Equilibrium between parent and progeny is not assumed.

Unconditional Derived Release Limits

Table 5.1 of the *Guidelines* provides a summary of the Unconditional Derived Release Limits calculated for the significant NORM nuclides in the Uranium and Thorium decay series and for potassium-40.

References

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Eckerman K.F. and Ryman J.C. (1993). Federal Guidance Report No. 12: External exposure to radionuclides in air, water, and soil. EPA 402-R-93-081. U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, DC.

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F Appendix

Elements of a Formal Radiation Protection Program

Radiation Protection Program

Employers that implement a radiation protection program should, as part of that program, keep the exposure to radon progeny and the effective dose received by and committed to persons as low as reasonably achievable through the implementation of:

- (i) management control over work practices;
- (ii) personnel qualification and training;
- (iii) control of occupational and public exposure to radiation; and
- (iv) planning for unusual situations.

An employer should ascertain the exposure to radon progeny and the effective dose by direct measurement as a result of monitoring; or by expert estimates.

Provision of Information

- (1) The employer shall inform each occupationally exposed worker, in writing:
 - (a) that he or she is an occupationally exposed worker;
 - (b) of the risks associated with radiation to which the worker may be exposed in the course of his or her work, including the risks associated with the exposure of embryos and fetuses to radiation;
 - (c) of the applicable radiation dose limits for occupationally exposed workers shown in Table 2.1; and
 - (d) of the worker's radiation dose levels.
- (2) The employer should inform each occupationally exposed female worker, in writing, of the applicable effective dose limits shown in Table 2.1.
- (3) The employer should obtain from each occupationally exposed worker a written acknowledgement that the worker has received this information.

Use of Licensed Dosimetry Service

Employers should use a dosimetry service, meeting the requirements of S-106, Technical and Quality Assurance Standards for Dosimetry Services in Canada, to measure the radiation doses to occupationally exposed workers who have a reasonable probability of receiving an effective dose greater than 5 mSv in a one-year dosimetry period.

Occupationally Exposed Workers

An occupationally exposed worker should on request of the employer provide the worker's:

- (a) given names, surname and any previous surname;
- (b) Social Insurance Number;
- (c) gender;
- (d) date, province or state and country of birth; and
- (e) dose record for the current one-year and five-year dosimetry periods.

Pregnant Occupationally Exposed Workers

Every occupationally exposed worker who becomes aware that she is pregnant should immediately inform the employer in writing.

On being informed by an occupationally exposed worker that she is pregnant, the employer should make accommodation to comply with Note (b), Table 2.1, that will not constitute undue hardship to the employer.

When Dose Limit Exceeded

When an employer becomes aware that a dose of radiation received by and committed to a person may have exceeded an applicable dose limit shown in Table 2.1, the employer shall:

- (a) immediately notify the person and the Provincial Authorities of the dose;
- (b) require the person to leave any work that is likely to add to the dose;
- (c) conduct an investigation to determine the magnitude of the dose and to establish the causes of the exposure;
- (d) identify and take any action required to prevent the occurrence of a similar incident; and
- (e) within 21 days after becoming aware that the dose limit has been exceeded, report the results of the investigation to the appropriate government authority (reference Appendix B) or on the progress that has been made in conducting the investigation.

Return to Work

If a person has received or been committed to an equivalent dose that exceeds an equivalent dose limit given in Table 2.1, and Provincial Authorities agree that the person can return to work, the authorization may specify conditions and prorated dose limits.

For the purpose of this section a prorated effective dose limit is the product obtained by multiplying the applicable dose limit given in Table 2.1 by the ratio of the number of months remaining in the dosimetry period to the total number of months in the dosimetry period.

Labelling and Signs

Labelling of Containers and Devices

Containers that store NORM radioactive material should be labelled with:

- (a) the radiation warning symbol set out in Figure G-1 and the words "RAYONNEMENT — DANGER — RADIATION"; and
- (b) the name, quantity, date of measurement and form of the radioactive material in the container.

This does not apply to a container used to hold radioactive material for current or immediate use or in which the quantity of radioactive material is less than or equal to the amounts shown in Table 5.1. For transporting radioactive materials refer to Section 6, Standards for the Transport of NORM.

Posting of Signs at Boundaries and Points of Access

The employer should place a durable and legible sign that bears the radiation warning symbol shown in Figure G-1 and the words "RAYONNEMENT — DANGER — RADIATION", at the boundary, and at every point of access to the area, room or enclosure:

where,

- (a) there is radioactive material present in an activity greater than 100 times the value shown in Table 5.1 in an area, room, or enclosure;
- or,
- (b) there is a reasonable probability that a person in the area, room or enclosure will be exposed to a radiation dose rate greater than 25 $\mu\text{Sv/h}$.

Use of Radiation Warning Symbol

Whenever the radiation warning symbol is used it should be:

- (i) prominently displayed;
- (ii) of an appropriate size for the size of the container to which it is attached, or of the area, room, enclosure or vehicle for which it is posted;
- (iii) oriented with one blade pointed downward and centred on the vertical axis;
- (iv) no wording shall be superimposed on it.

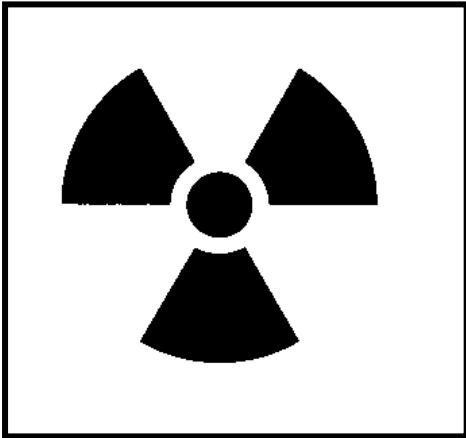
Frivolous Posting of Signs

A radiation warning sign should not be posted at a place where the radiation dose rate or radioactive material indicated on the sign is not present.

Records to Be Kept by Employer

Every employer should keep a record of the name and job category of each occupationally exposed worker.

Figure G-1 Radiation Warning Symbol



Note:

The three blades and the central disk of the symbol shall be:

- (a) magenta or black; and
- (b) located on a yellow background.

G Appendix

Glossary Of Radiation Terminology

Absorbed Dose: The mean energy deposited by ionizing radiation per unit mass of the body or organ or tissue of the body. Unit: gray (Gy), 1 Gy = 1 joule per kilogram.

Activity (Radioactivity): The number of nuclear transformations that occur in a quantity of material per unit of time. Unit: becquerel (Bq), 1 Bq = 1 disintegration per second.

ALARA: A principle of risk management according to which exposures are kept as low as reasonably achievable, economic and social factors being taken into consideration. A guiding principle of radiation protection.

Alpha Radiation (Alpha Decay): A high-energy positively charged particle ejected from the nucleus of an unstable (radioactive) atom, consisting of two protons and two neutrons. An alpha particle is a helium nucleus.

Annual Limit on Intake (ALI): The intake by inhalation, ingestion or through the skin of a given radionuclide in a year by a reference man which would result in a committed dose equal to the relevant dose limit. The ALI is expressed in units of activity.

Atomic Number: The number of protons contained in the nucleus of an atom. This number gives each atom its distinct chemical identity.

Atomic Mass (Mass Number): The total mass of protons and neutrons contained in the nucleus of an atom.

Background Radiation: The radiation to which an individual is exposed arising from natural radiation sources such as terrestrial radiation from radionuclides in the soil, cosmic radiation from space, and naturally occurring radionuclides deposited in the body from foods, etc.

Balance of Pregnancy: The period from the moment an employer is informed of the pregnancy to the end of the pregnancy.

Becquerel (Bq): An SI unit of radioactivity, equivalent to 1 nuclear transformation per second. Used as a measurement of the quantity of a radionuclide since the number of radioactive transformations (disintegrations) is directly proportional to the number of atoms of the radionuclide present. Replaces an earlier unit, the curie (Ci).

Beta Radiation (Beta Decay): The ejection of a high-energy negatively charged subatomic particle from the nucleus of an unstable atom. A beta particle is identical in mass and charge to an electron.

Contamination (Radioactive Contamination): Radioactive material present in excess of natural background quantities in a place it is not wanted.

Committed Dose: The total dose received from a radioactive substance in the body during the remainder of a person's life (assumed as 50 years for adults, 70 years for children) following the intake of the radionuclide.

Curie (Ci): A unit of activity equivalent to 3.7×10^{10} disintegrations per second. Replaced in international usage by the becquerel.

Decay (Radioactive Decay): A process followed by an unstable nucleus to gain stability by the release of energy in the form of particles and/or electromagnetic radiation. NORM materials decay with the release of alpha particles, beta particles and/or gamma photons.

Decay Series (Radioactive Decay Series): A succession of radionuclides, each member of which transforms by radioactive decay into the next member until a stable nuclide results. The first member is called the “parent”, the intermediate members are called “progeny” and the final stable member is called the “end product”. In the two NORM decay series; uranium-238 and thorium-232 are the “parents,” and lead-206 and lead-208 are the “end products”.

Derived Working Limit (DWL): A practical working limit derived from regulatory limits. Derived Working Limits can be compared to measured values at the work site to assess compliance with regulatory limits.

Diffuse NORM: NORM-contaminated material in which the radioactive concentration is uniformly dispersed. It is generally low in radioactive concentration, and relatively large in volume.

Discrete NORM: NORM-contaminated material in which radioactive substances are concentrated, or not uniformly dispersed throughout the material. It generally has much higher levels of radioactive concentration in a localized volume than diffuse NORM.

Dose Coefficient (DC): A factor that relates the amount of radiation dose (Sv) delivered to the body per unit of activity (becquerel) taken into the body. Unit: (Sv/Bq).

Dose Constraint: An upper bound on the annual dose that members of the public or incidentally exposed workers should receive from a planned operation or single source.

Dosimeter: A device for measuring a dose of radiation that is worn or carried by an individual.

Effective Dose: Radiation dose for primary radiation dose limits. It represents the sum of the equivalent doses received by different tissues of the human body, each multiplied by a “tissue weighting factor” (w_T). Unit: sievert (Sv).

Equilibrium (Radioactive): In a radioactive decay series, the state that prevails when the rate at which progeny are produced is equal to the rate at which they are decaying. This form of equilibrium may be attained only if the precursor is very long-lived relative to any member of the decay chain. All members of a NORM radioactive decay series in equilibrium have the same radioactivity.

Equivalent Dose: The absorbed dose multiplied by a “radiation weighting factor”, (w_R), which accounts for the different potential for adverse effects of the different types of radiation. Unit: sievert (Sv).

Five Year Dosimetry Period: The period of five calendar years beginning on January 1 of the year following the year in which the Radiation Protection Management Program is started, and every period of five calendar years thereafter.

Gamma Radiation (Gamma Rays or Gamma Photons): Electromagnetic radiation or photon energy emitted from an unstable nucleus in the process of ridding itself of excess energy. Highly penetrating, gamma rays lose energy as they pass through atoms of matter.

Gray (Gy): Radiation damage is dependent on the absorption of radiation energy and is approximately proportional to the concentration of absorbed energy in tissue. The gray is the SI unit of absorbed radiation dose corresponding to the absorption of 1 joule of radiation energy per kilogram of material. For gamma and beta radiations, the gray is numerically equal to the sievert.

Groundshine: Radiation detectable on the earth's surface from radioactive substances on or beneath the surface.

Half-life, Biological: The time required for the body to eliminate half the quantity of a substance taken into the body. A major factor in determining a radionuclide's Dose Coefficient.

Half-life, Radioactive: The time required for a radioactive material to lose half of its activity through radioactive decay.

IAEA: International Atomic Energy Agency.

ICRP: International Commission on Radiological Protection.

Incidentally Exposed Workers: Employees whose regular duties are not expected to result in exposure to NORM radiation. The public annual dose limit of 1 mSv applies to this category of workers in an occupational exposure environment - the occupational domain.

Incremental Dose: Radiation dose found in excess of the local background radiation dose.

NORM (Naturally Occurring Radioactive Materials): NORM is an acronym for naturally occurring radioactive materials comprising radioactive elements found in the environment. Long-lived radioactive elements of interest include uranium, thorium and potassium and any of their respective radioactive decay products such as radium and radon. Some of these elements have always been present in the earth's crust and within the tissues of all living beings. Although the concentration of NORM in most natural substances is low, higher concentrations may arise as the result of human activities.

One-year Dosimetry Period: The period of one calendar year beginning on January 1 of the year following the year in which the Radiation Protection Management Program is started, and every period of one calendar year thereafter.

Occupationally Exposed Workers (NORM Workers): Employees who expect to receive exposure to sources of NORM radiation as a result of their regular duties. The annual occupational dose limit of 20 mSv applies to this category of workers in an occupational exposure environment.

Personal Dosimetry Threshold: The annual effective dose above which radiation dosimetry of individual workers is required.

Phosphogypsum Stack: Phosphogypsum stack refers to the storing of phosphogypsum, a byproduct of fertilizer production, in large outdoor stockpiles.

Photons (X-ray or Gamma rays): See gamma radiation.

Rad: A historical radiation unit for measuring radiation energy absorption (dose), equivalent to 100 ergs per gram in any medium. RAD is an acronym for Radiation Absorbed Dose. Now replaced in international system of units by the “gray” (Gy).

Radiation Weighting Factor (w_R): A value recommended by the International Commission on Radiological Protection, and usually adopted by national regulatory agencies, to convert absorbed dose from various types of ionizing radiation into its dose equivalent in terms of biological harm from alpha, beta or gamma radiation. For gamma rays and beta particles, $w_R = 1$. For alpha particles and fast neutrons, $w_R = 20$.

Radiochemical Analysis: Analysis of the radioactive content of a NORM sample. Radiochemical analysis will identify and quantify the concentration of various radionuclides in the NORM sample.

Radionuclide or Radioisotope: A particular form of an element, characterized by a specific atomic mass and atomic number, whose atomic nucleus is unstable and decays or disintegrates with a statistical probability characterized by its physical half-life.

Radium-226: A radioactive element with a half life of 1600 years. It is a particularly hazardous decay product of natural uranium, and is frequently the dominant NORM nuclide. It decays into the radioactive gas Radon-222.

Radon: The only radioactive gas generated during natural radioactive decay processes. Two radioisotopes of radon are present — radon and thoron — each a decay product of radium. Radon (Rn-222) is found in the uranium decay series while thoron (Rn-220) is found in the thorium decay series.

Radon Progeny: The products of radon (radon-222) or thoron (radon-220) decay with short half-lives. Radon decay products include; Polonium-218 (RaA), Lead-214 (RaB), Bismuth-214 (RaC), and Polonium-214 (RaC'). Thoron decay products include; Polonium-216 (ThA), Lead-212 (ThB), Bismuth-212 (ThC), Polonium-212 (ThC'), and Thallium-208 (ThC'')

Rem: A historical unit of human dose equivalent. Rem is an acronym for roentgen equivalent man and was replaced in 1977 by the sievert in the international system of units.

Roentgen (R): The classical unit of radiation ionization in air, frequently misapplied as a unit of exposure in humans. Replaced in international system of units by the “coulomb per kg in air”.

Shielding: The reduction of radiation beam intensity by interposing, between the source and an object or person that might be exposed, a substance that absorbs radiation energy, either by collision, in the case of particulate radiation, or by absorption of waveform energy, in the case of gamma photons.

SI (Systeme Internationale): The “metric” system of units generally based on the metre/kilogram/second units. Special quantities for radiation include the becquerel, gray and sievert.

Sievert (Sv): The sievert is the unit of radiation equivalent dose, H, that is used for radiation protection purposes, for engineering design criteria and for legal and administrative purposes. The

sievert is the SI unit of absorbed radiation dose in living organisms modified by radiation type and tissue weighting factors. The unit of dose for the terms “equivalent dose” and “effective dose”. It replaces the classical radiation unit the rem. Multiples of sieverts (Sv) used in the *Guidelines* include millisieverts (mSv) and microsieverts (μSv).

Specific Activity (Radioactive Concentration): The number of becquerels per unit of mass of a material. Units: Bq/g and kBq/kg

Tissue Weighting Factor (w_T): A weighting factor developed by the ICRP that assigns a relative share of total radiation dose detriment to specific organs and tissues. Risks from localized radiation exposures to specific organs and tissues can be quantified.

Unconditional Derived Release Limits (UDRL): Within the Unrestricted classification, the radioactive activity of NORM below which NORM can be released into the public domain without restrictions.

Working Level (WL): A unit for potential alpha energy concentration, (PAEC), resulting from the presence of radon progeny equal to the emission of 1.3×10^5 MeV of alpha energy per litre of air. In SI units the WL corresponds to 2.08×10^{-5} joules per cubic metre (J/m^3).

Working Level Month (WLM): A measure of the cumulative exposure to radon progeny in air. One Working Level Month is defined as the exposure received by an individual inhaling air containing a radon progeny concentration of one WL for a period of 170 hours, the assumed number of hours in a working month. One working level month is equivalent to 3.54 mJ h m^{-3} .