Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

Canada

Dosimetry and Dose Assessment

CNSC Staff Presentation
Commission Meeting
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CMD 21-M29

nuclearsafety.gc.ca

e-Docs 6641382 (PPTX)
e-Docs 6641527 (PDF)

Canada

Purpose

The purpose of the presentation is to provide a technical briefing on dosimetry and dose assessment approaches.

The briefing is for information and no decision is being requested of the Commission.

Presentation Outline

- Regulatory Requirements
- Overview of Dosimetry
- Case Studies (2)
- Summary

Regulatory Requirements

Dosimetry and Dose Assessment

Regulatory Requirements (1/3)

- The Canadian Nuclear Safety Commission regulates the use of nuclear energy and materials to protect health, safety, security and the environment
- The *Radiation Protection Regulations* (RPR) set dose limits and require that licensees implement a radiation protection program to keep doses received by persons as low as reasonably achievable

Regulatory Requirements (2/3)

Radiation Protection Regulations

subsection 5(1)

That every licensee must **ascertain and record** the doses of radiation received by persons present or performing work in connection with licensed activities

Regulatory Requirements (3/3)

Radiation Protection Regulations
subsection 5(2)

Doses shall be determined by:

Direct measurement through monitoring

or

Estimation

It is up to the licensees to demonstrate if estimation is an appropriate method for the assessment of dose.

The proposed method is reviewed by CNSC staff for acceptability.

Requirement to use Licensed Dosimetry

Licensees **must use licensed dosimetry** for nuclear energy workers (NEW) who may receive an:

- Effective dose greater than 5 mSv in a one-year dosimetry period
- Equivalent dose to the skin or to the hands and feet greater than 50 mSv in a one year dosimetry period

CNSC Licensed Dosimetry Services

- A dosimetry service measures and monitors doses of radiation
- Doses measured by a dosimetry service for a NEW must be submitted to the National Dose Registry
- Dosimetry services must meet technical and management system requirements in CNSC REGDOC 2.7.2, Vol II

Licensed dosimetry results are accurate, repeatable, verifiable and properly recorded

Overview of Dosimetry

Dosimetry and Dose Assessment

Methods for Ascertaining Doses

The RPR provides some flexibility in the methods for ascertaining doses to persons:

- **direct monitoring**: personal dosimetry
- **indirect monitoring**: workplace monitoring
- **dose modelling**: calculation approach

The choice of dosimetry should be consistent with the potential risk of the exposure

Understanding the Conditions (1/2)

Characterization of radiation conditions in a workplace takes into consideration:

- The nuclear substances that are expected to be present in the workplace
- The radiation types and energies emitted by the nuclear substances
- The physical form (solid, liquid, gas), source geometry and shielding information

Understanding the Conditions (2/2)

The range and penetrating ability of each radiation type influences which tissues are at greater risk of exposure and will directly inform the type of dosimetry required.

Types of Radiological Exposures

External

When a person is exposed to a source of radiation outside of the body

Internal

When a nuclear substance is taken into the body through ingestion, inhalation, injection or absorption through the skin

External Exposure - Direct Monitoring

Two types of dosimeters are commonly used:

Passive dosimeters

Radiation signal stored in the device

Active dosimeters

Radiation reading of detected dose or dose rate is displayed in real-time

Quality of Dosimeter Results

Factors that can influence the quality of a dosimeter's result

- How the dosimeter is worn by the worker
- How and where a dosimeter is stored when not in use
- Environmental conditions such as direct sunlight, extreme temperature, dust, humidity
- Dosimeter response can depend on the radiation energy and angle of incidence

External Dosimetry: Whole body

Most whole body dosimeters measure two quantities:

Deep dose
Represents external component of *effective dose*

Shallow dose
Represents *equivalent dose* to the skin

External Dosimetry: Extremities

Worn on the extremities to measure shallow dose to the hands and feet

External Dosimetry: Lens of the Eye

- Whole body dosimeters provide a reasonable approximation of lens of eye dose in many exposure situations
- Certain exposure situations may require additional direct monitoring of the lens

There is no regulatory requirement to use licensed dosimetry to ascertain dose to the lens of the eye

External Dosimetry: Neutron Dosimetry

Passive dosimeter which uses particle track detection technology

Active neutron dosimetry determines personal dose from the results of workplace measurements combined with occupancy time

Internal Dosimetry

Determines the dose from nuclear substances taken into the body.

Understand radiological conditions in the workplace to select the best monitoring approach

Assess what types of individual monitoring should be used to detect potential intakes and when detected, to ascertain doses

Monitoring workers is done through individual and/or workplace measurements

Individual Monitoring

Individual monitoring may consist of measuring nuclear substances **in the body** or monitoring substances **excreted from** the body.

In vivo	***In vitro***
"in the body"	*"in glass"*
Measuring radiation emitted by nuclear substances within the body using detectors that are positioned near the body.	Measuring the quantity of nuclear substances excreted from the body in order to determine the quantity that is in the body.

Factors to Consider in Selecting Approach

- The range and type of radiation emitted by the nuclear substance taken into the body
- The half life and solubility of the nuclear substance
- How the nuclear substance distributes within the body
- The likelihood of intakes during normal operations and during upset conditions
- The potential magnitude of the resultant dose

In vivo Monitoring

- Substances must emit radiation with sufficient range to escape the body (e.g., photon radiation)
- *In vivo* monitoring results are normally the most accurate because they are a direct measurement of the amount of nuclear substances in the body
- *In vivo* monitoring methods include whole-body monitoring and partial body monitoring

In vivo Monitoring Methods

In vitro Monitoring

- Used to detect intakes when the nuclear substance taken into the body cannot be detected from outside
- Measurement of a human sample is required
- Routine monitoring involves collecting and analyzing samples at scheduled intervals during normal operations
- Non-routine monitoring is implemented in response to a particular circumstance

In vitro Monitoring Methods

Internal Dosimetry: Calculating Dose

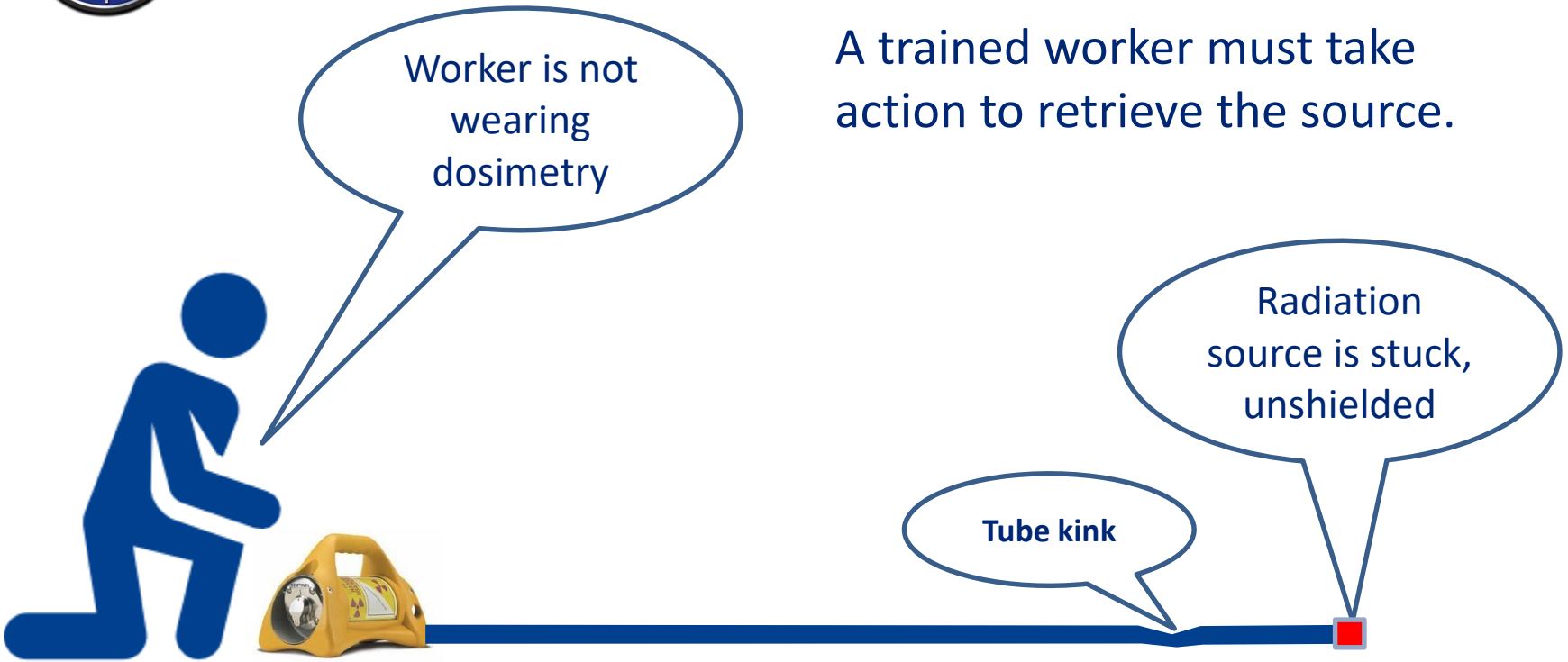
Case Studies

External dose assessment

Internal dose assessment

External Dose Assessment (1/3)

A trained worker must take action to retrieve the source.



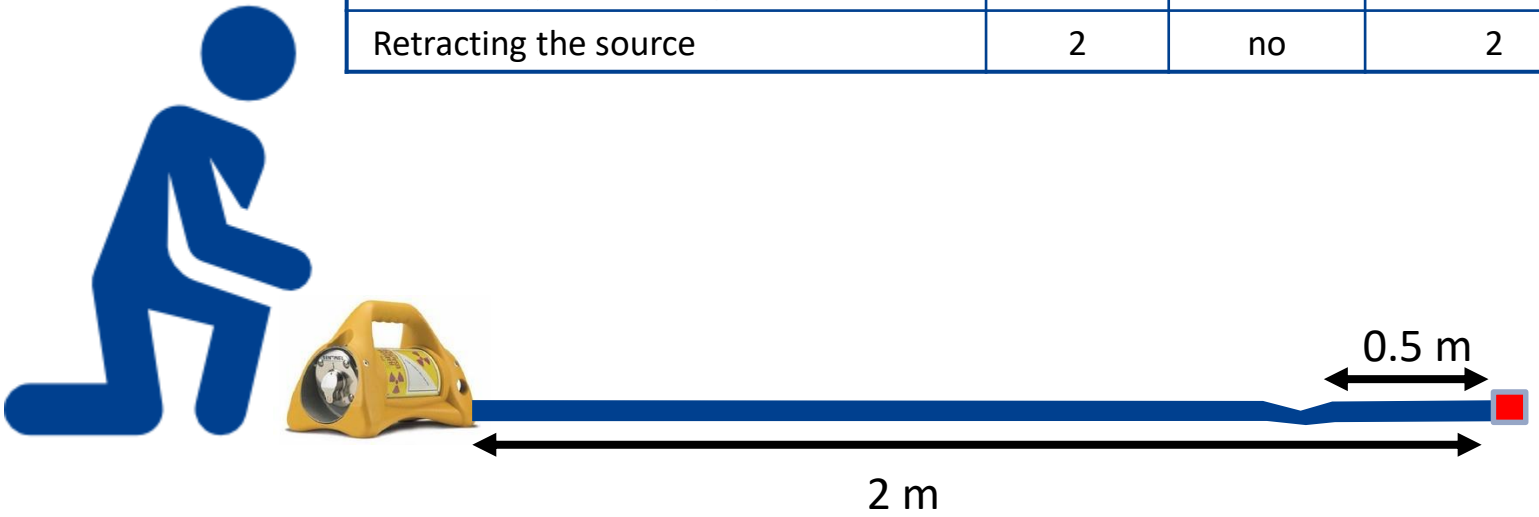
External Dose Assessment (2/3)

Iridium-192	
Source Activity (GBq)	4660
Gamma Ray Constant (mSv/h per GBq at 1 meter)	0.117

$$\textit{Dose Rate} = \frac{\textit{activity X gamma ray constant}}{\textit{distance}^2}$$

External Dose Assessment (3/3)

Source Retrieval Steps	Distance (m)	Source Shielded	Exposure time (min)	Dose (mSv)
Preparing for the recovery	2	no	2	4.5
Work to repair kink in guide tube	0.5	no	1	36
Retracting the source	2	no	2	4.5
				45 mSv

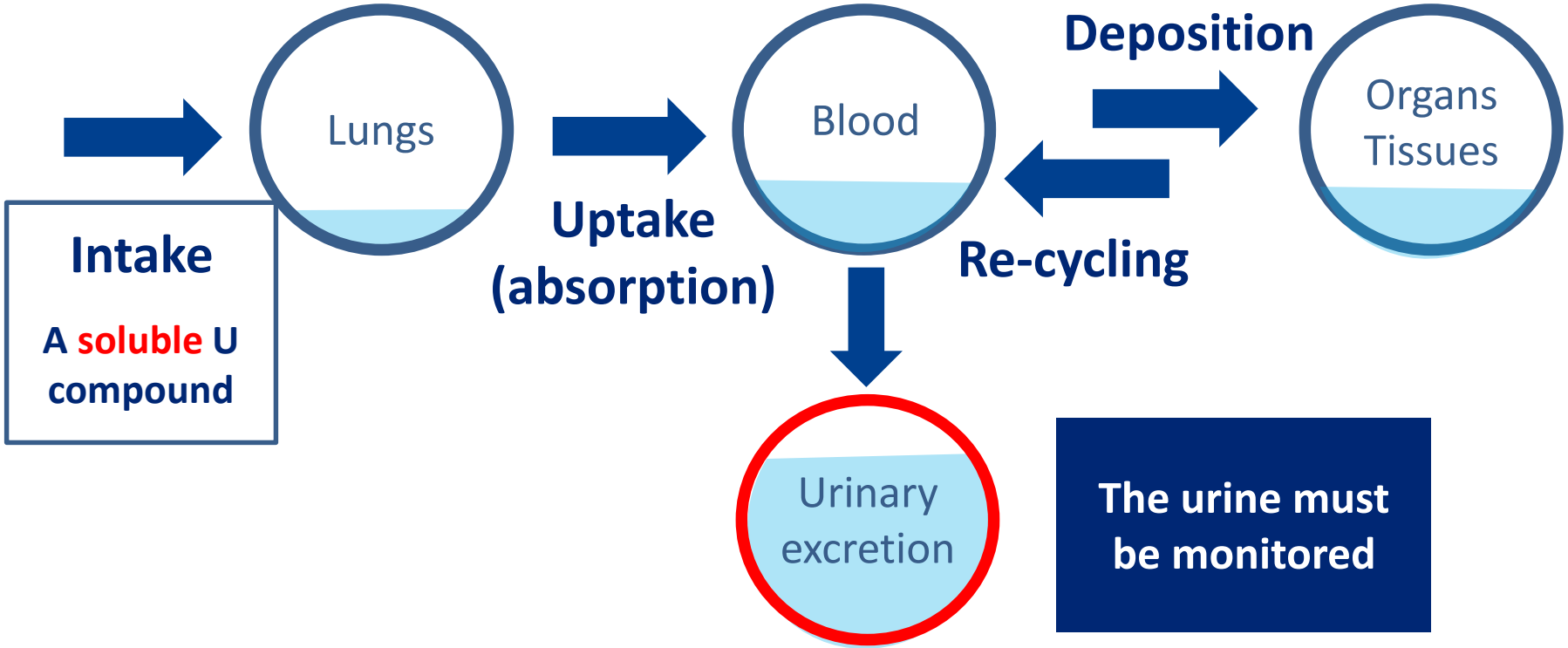


Internal Dose Assessment

- Licensee reported elevated post-shift urine sample of worker
- Follow-up urine samples were collected
- The licensee compiled the monitoring results and data on the material characteristics

CNSC independently ascertained the dose based on the licensee's data

Solubility of uranium compounds

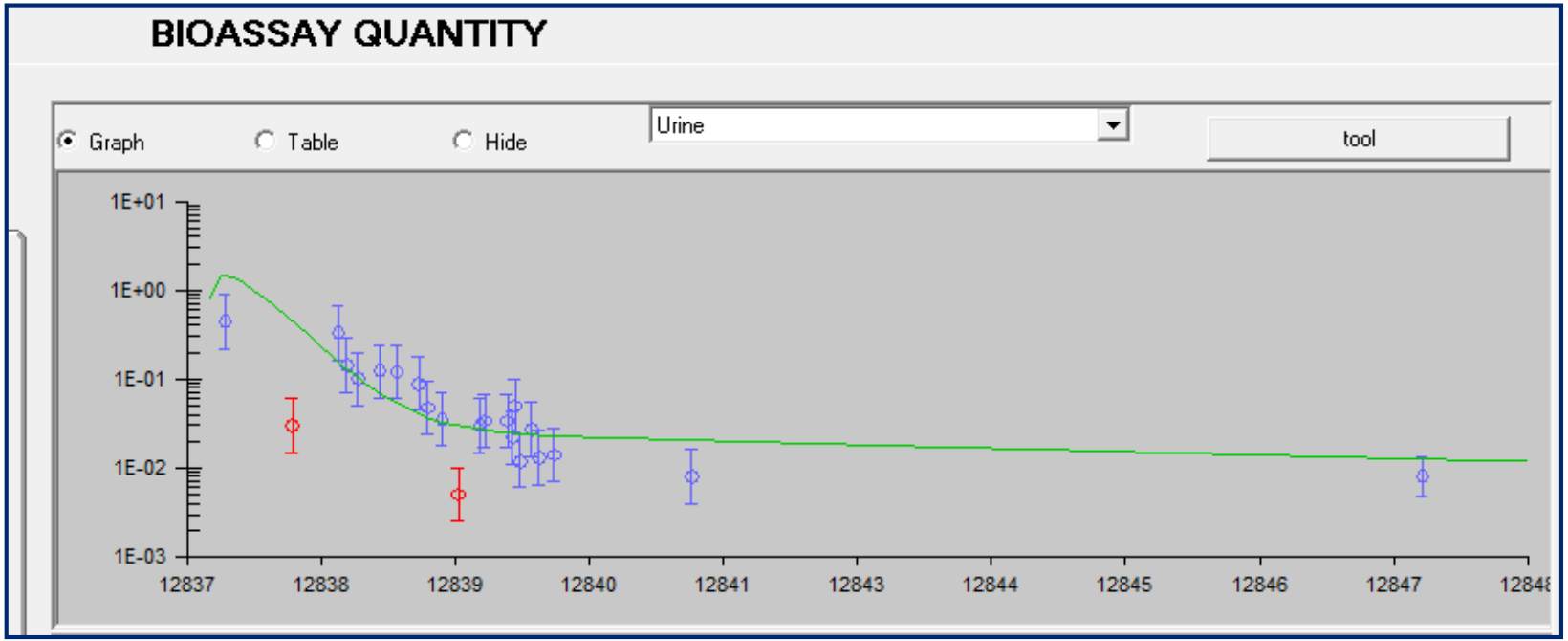


Data Required to Ascertain the Dose

- ✓ The licensee had characterized the workplace by measuring the solubility parameters. These were input into dosimetry software
- ✓ The time of the event leading to the intake was known
- ✓ The licensee submitted all monitoring results (date, time, uranium in urine concentration, sample volume)

Bioassay Data compared to model

Maximum likelihood method used to fit ICRP curve to data.



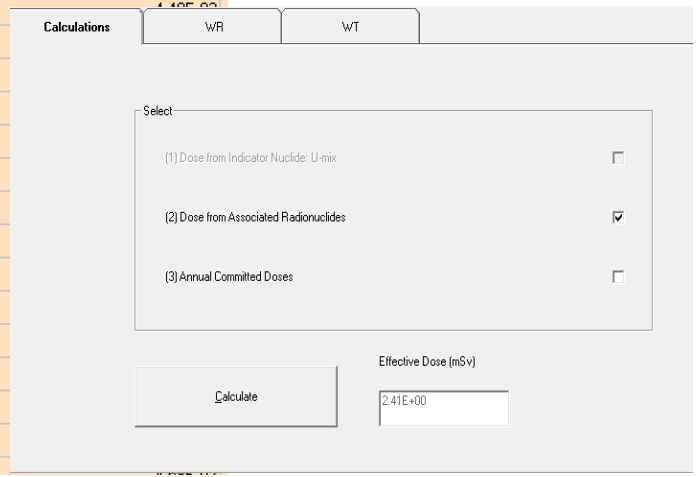
Excretion rate
(mg uranium excreted/day)

Days (12837 = date of intake)

Analysis results

The software calculates equivalent and effective dose

Target Organs	Eq. Dose U-234 (mSv)	Eq. Dose U-235 (mSv)	Eq. Dose U-236 (mSv)	Eq. Dose U-238 (mSv)	TOTAL (mSv)
Adrenals	2.32E-02	1.02E-03	0.00E+00	2.07E-02	4.49E-02
Urinary Bladder	2.33E-02	1.01E-03	0.00E+00	2.08E-02	4.50E-02
Brain	2.32E-02	1.01E-03	0.00E+00	2.07E-02	
Breast	2.32E-02	1.02E-03	0.00E+00	2.07E-02	
Gall Bladder	2.32E-02	1.01E-03	0.00E+00	2.07E-02	
Heart Wall	2.32E-02	1.03E-03	0.00E+00	2.08E-02	
Kidneys	2.44E-01	1.06E-02	0.00E+00	2.17E-01	
Liver	9.12E-02	3.95E-03	0.00E+00	8.12E-02	
Muscle	2.32E-02	1.01E-03	0.00E+00	2.07E-02	
Ovaries	2.32E-02	1.01E-03	0.00E+00	2.07E-02	
Pancreas	2.32E-02	1.02E-03	0.00E+00	2.07E-02	
Testes	2.32E-02	1.00E-03	0.00E+00	2.07E-02	
Thyroid	2.32E-02	1.01E-03	0.00E+00	2.07E-02	
R.B.M.	6.87E-02	3.00E-03	0.00E+00	6.31E-02	
Bone Surface	6.64E-01	2.87E-02	0.00E+00	5.92E-01	
Stomach	2.34E-02	1.02E-03	0.00E+00	2.09E-02	



Committed effective dose: 2.4 mSv

Summary

Dosimetry and Dose Assessment

Summary Points

- Dosimetry is part of the radiation protection program
- Licensees are responsible for selecting dosimetry methods that are suitable for their radiological conditions
- Direct monitoring is the most reliable method
- The results of dose assessments can change significantly depending on the assumptions used
- When required, licensees conduct dose assessments and CNSC staff verify approach and calculations

Additional Resources

- REGDOC 2.7.1, *Radiation Protection*
- REGDOC 2.7.2, Volume I, *Ascertaining Occupational Dose*
- REGDOC 2.7.2 Volume II, *Technical and Management System Requirements for Dosimetry Services*
- CNSC's Radionuclide Information Booklet
- Radiation doses - Canadian Nuclear Safety Commission

Questions?

Thank You!