Australian Government
Australian Radiation Protection and Nuclear Safety Agency

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Radiation Safety in Laboratories

Stephen Long

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SOUTH PACIFIC ENVIRONMENTAL RADIOACTIVITY ASSOCIATION

Workshop Outline

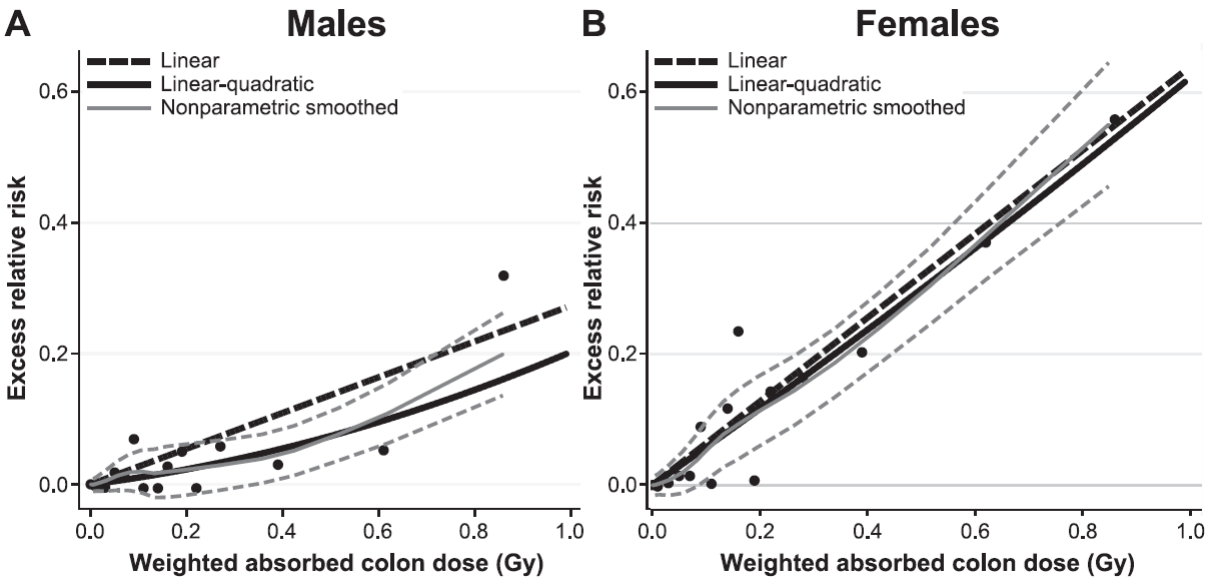
- The International System of Radiological Protection
- The Australian Standard for Radiation Safety in Laboratories
- Personal Radiation Monitoring
- Group Discussion

The International System of Radiological Protection

Radiation Risks

- Tissue Effects
  - High doses above a threshold
  - Severity increases with dose

- Probabilistic Effects
  - Moderate and low doses
  - Incidence increases with dose

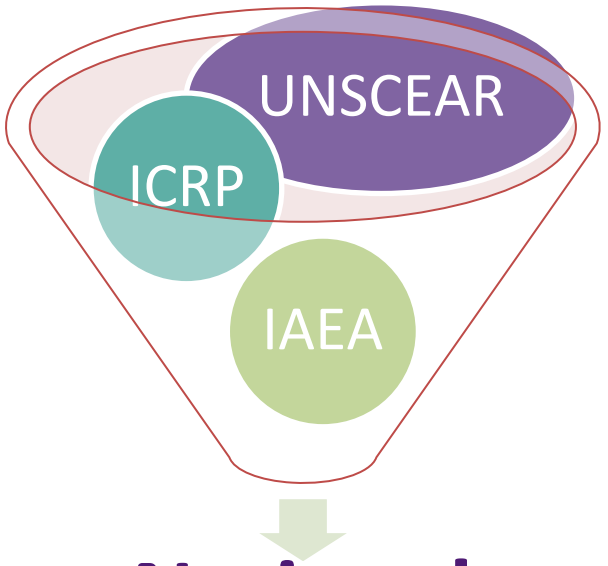


Aims of Radiation Protection

- **Prevent** Tissue Effects
- **Minimise** Probabilistic Effect
- **Balance** Risks and Benefits

International Organisations

- **UNSCEAR** reviews and assesses the effects of atomic radiation
- **ICRP** provides recommendations
- **IAEA** establishes standards of safety and provides for the application of the standards



Fundamental Principles

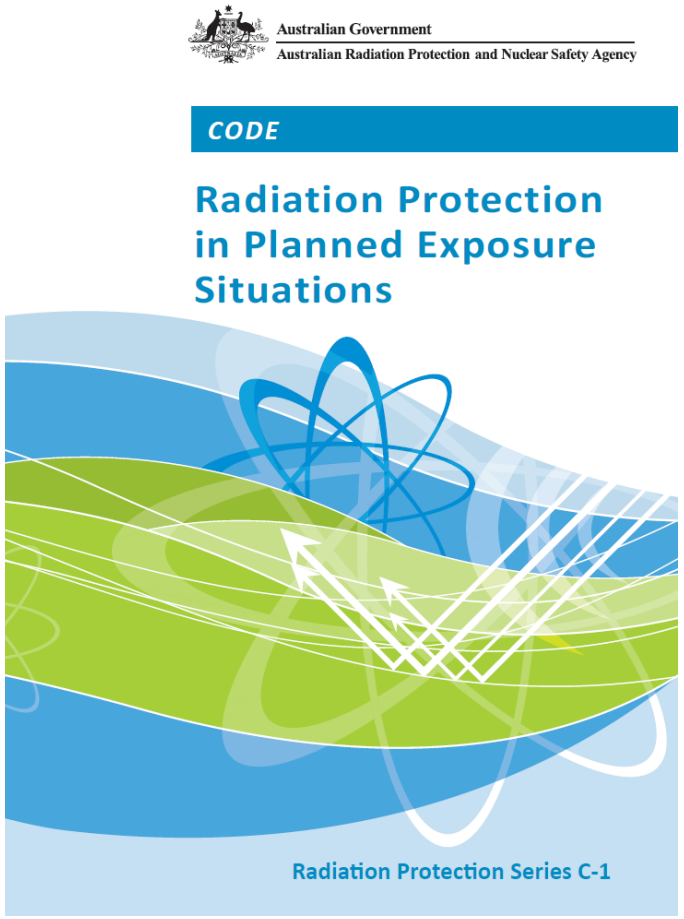
- **Justification**
  - doing more good than harm
- **Optimisation**
  - keeping doses as low as reasonably achievable
- **Limitation**
  - ensuring no-one receives an unacceptably high dose

Exposure Situations and Categories

	Occupational Exposure	Public Exposure	Medical Exposure
Planned	working in a hospital, uranium mine, or **laboratory**	visiting a hospital, living near a nuclear power plant	getting an x-ray, CT scan, or radiation treatment
Existing	aircrew exposed to radiation from outer space	radon gas in the home	N/A
Emergency	in the immediate response to an accident	during a major accident	N/A

Planned Exposure Code

"… set out the requirements in Australia for the protection of **occupationally exposed persons**, the **public** and the **environment** from the harmful effects of ionising radiation in planned exposure situations."



Regulatory Authorities

AS/NZS 2243.4

Safety in Laboratories

Part 4: Ionizing Radiations

Background

- Part of ***Safety in Laboratories*** series
- First published in 1979
  - Recommended dose limits
  - No advice on laboratory design
- Revised in 1994
  - Incorporated NHMRC *Code of Practice for the Design of Laboratories using Radioactive Substances for Medical Purposes (1981)*
- Revised in 1998
  - Incorporated NHMRC and Worksafe Australia *Recommendations for limiting exposure to ionizing radiation* (1995) [NOHSC:3022] and *National standard for limiting occupational exposure to ionizing radiation* [NOHSC:1013 (1995)]

2243.1	Planning and operational aspects
2243.2	Chemical aspects and storage
2243.3	Microbiological safety and containment
2243.4	Ionizing radiations (this Standard)
2243.5	Non-ionizing radiations—Electromagnetic, sound and ultrasound
2243.6	Plant and equipment aspects
2243.8	Fume cupboards
2243.9	Recirculating fume cabinets

Background to 2018 Revision

- Include Standards New Zealand
  - Joint standard
- Includes recent recommendations by ARPANSA
  - *Fundamentals for Protection Against Ionising Radiation* RPS F1 (2014)
  - *Code for Radiation Protection in Planned Exposure Situations* RPS C1 (2016)
- Recognises that **ALL** laboratories are now regulated
  - ARPANSA, ANSTO, ANU, CSIRO unregulated prior to 1999
- Recognises National Directory for Radiation Protection

1 - Scope and General

- Standard sets out requirements for the protection of people, non-human biota and the environment from the harmful effects of ionizing radiation used in, or as a result of any use within, or in connection with a laboratory
- Where requirements given in this Standard differ from requirements under jurisdictional legislation, the legislation takes precedence.
- Standard shall be implemented in all laboratories in which—
  (a) radioactive materials are used, processed or stored; or
  (b) ionizing radiation apparatus is used.

2 - Hazards and Their Control

- For further information on the effects of radiation on health and the environment please see Fundamentals for Protection Against Ionising Radiation, RPS F1
- Legislation requires all persons who deal with ionizing radiation in their work shall do so under a licence. As the licensing requirements vary among the jurisdictions, each laboratory shall determine their obligations and comply with the applicable legislative requirements
- Risk assessments of all radiation operations in the laboratory shall be carried out. As part of the risk assessment, the information contained in various regulations and accompanying codes of practice and the other Parts of the AS/NZS 2243 series shall be incorporated where appropriate.

2 - Hazards and Their Control

- Protection from external hazards
  - Limit the exposure time.
  - Maximize the distance between source and person.
  - Use suitable shielding.
- Protection from internal hazards
  - Use of the least radiotoxic and smallest activity of radioactive material that is suitable for the task to be undertaken.
  - Containment, i.e. limit the laboratory area that could become contaminated with radioactive materials by the use of fume cupboards, glove boxes or safe handling techniques.
  - Cleanliness, i.e. high quality housekeeping techniques are essential.

3 - Design Requirements - General

3 types of laboratory:

- Radiation laboratories
  - in which ionizing radiation from ionizing radiation apparatus or sealed radioactive sources are used or stored.
- Radioisotope laboratories
  - in which unsealed radioactive materials are used or stored.
- Radiological laboratories
  - in which ionizing radiation apparatus, sealed radioactive materials and unsealed radioactive materials are used.

3 – Design Requirements - Laboratory Grading

For Radioisotope and Radiological laboratories:

- Grading (low, medium, high) based on:
  - Radiotoxicity of radionuclides in use
  - Radioactivity of radionuclides in use
  - Types of operations carried out

Radiotoxicity

- Potential of radioactive material **when introduced into the body** to cause damage to living tissue by absorption of energy from the radiation it emits
- Based on inhalation Dose Conversion Factor
- Modified by Specific Activity of radioisotope
  - For two radionuclides with equal DCFs in terms of mSv/Bq the one with the greater conversion factor in terms of mSv/g would be the more hazardous.
- 4 Groups
  - Table lists over 300 commonly used radioisotopes

Base Laboratory Grading

Radiotoxicity group	Grade of laboratory for specified levels of activity		
	Low level laboratory	Medium level laboratory	High level laboratory
1	<0.2 MBq	0.2 MBq to 20 MBq	>20 MBq
2	<20 MBq	20 MBq to 2 GBq	>2 GBq
3	<2 GBq	2 GBq to 0.2 TBq	>0.2 TBq
4	<0.2 TBq	0.2 TBq to 20 TBq	>20 TBq

Assumes normal, wet chemical operations

Modifying Factors

Procedure	Factor
Simple storage	×100
Very simple wet operations (e.g. using aliquots of stock solutions)	×10
Very simple wet operations incorporating biological or organic compounds	×1
Normal chemical operations (e.g. analysis of simple chemical preparations)	×1
Normal chemical operations incorporating biological or organic compounds	×0.1
Complex wet operations (e.g. multiple operations, or operations with complex glass apparatus)	×0.1
Complex wet operations incorporating biological or organic compounds	×0.01
Simple dry operations (e.g. manipulations of powders) and work with volatile radioactive compounds	×0.01
Simple dry operations incorporating biological or organic compounds	×0.001
Complex dry operations (e.g. where powders are likely to become airborne) and work with radioactive gases	×0.001

3 – Design Requirements

	Low	Medium	High	Comments
General comments	Criteria as itemized in AS/NZS 2982 *(Laboratory design and construction)* RPA to review design and organization for conformance	Criteria as itemized in AS/NZS 2982 *(Laboratory design and construction)* RPA to be consulted at the design stages for conformance Conformance with appropriate parts of ARPANSA RPS 14, IAEA *Applying Radiation Safety Standards in Nuclear Medicine* and IAEA *Operational Guidance on Hospital Radiopharmacy* Laboratory is solely dedicated to radiation work Overshoes may be required Uniquely identifiable laboratory coats	Refer to AS/NZS 2982 *(Laboratory design and construction)* RPA to be consulted at the design stages for conformance Access will be via change room Conformance with appropriate parts of IAEA *Applying Radiation Safety Standards in Nuclear Medicine* and IAEA *Operational Guidance on Hospital Radiopharmacy* Overshoes may be required Uniquely identifiable laboratory coats	Other requirements may be specified by local radiological regulators, such as the New Zealand Ministry of Health, and non-radiological regulators, such as the Office of the Gene Technology Regulator, WorkSafe New Zealand, etc.

3 – Design Requirements

Table of requirements – dependant on laboratory grading:

- Structural shielding
- Flooring
- Floor penetrations
- Bench tops
- Joins
- Sinks
- Drainage
- Ventilation
- Fume cupboard
- Handwashing basin
- First-aid
- Radioactive materials storage
- Access
- Coat hooks
- Write-up area
- Emergency Shower

4 – Radiation Protection

- **All planned exposures shall be justified and optimized.**
- **Hierarchy of controls**
  - Elimination of exposure, where practicable.
  - Minimize activity and radiotoxicity
  - Isolation of sources
  - Engineering controls
  - Administrative controls
  - Personal protective equipment
- **Designated Radiation Areas**
  - Controlled areas - areas where there is the potential for significant internal or external exposure from radiation
  - Supervised areas – may be subject to increased radiation but in which specific protection measures are not needed
- **Radiation warning signs must be displayed at the entrances to each designated radiation area**

4 – Radiation Protection

- Local Instructions
  - Specific procedures and requirements for each DRA
- Shielding shall be designed and installed in a manner that ensures that the dose received by any person is optimized and below dose limits
- All tasks to be carried out while working in isolation shall be subject to a risk assessment
- A worker, or other person, who is required to work alone in a laboratory outside of normal working hours, or work in an isolated or hazardous area, shall be provided with a method for summoning help

4 – Radiation Protection

Sealed Sources and Radiation Producing Apparatus

Whenever practicable, special enclosures, such as cabinets or rooms, shall be used to house ionizing radiation sources and apparatus producing ionizing radiations in such a way that, under all operating conditions, persons outside the enclosures are protected from the useful beam and from leakage and scattered radiation.

- Sealed Sources:
  - safety measures
  - labelling
  - record keeping
  - testing and maintenance
  - contingency management
  - Storage
- X-ray analysis apparatus
  - Interlocks should be provided
  - dose rate < 10 µSv/h
  - warning lights or illuminated signs
- Cabinet X-ray machines
- Particle accelerators

4 – Radiation Protection - Unsealed Sources

- **Precautions shall also be taken to prevent radioactive materials from being taken into the body by inhalation, ingestion, absorption through the skin or entry via a wound**
- Records of all stocks of unsealed radioactive materials shall be maintained
- The entrance to a controlled area shall contain all of the personal protective equipment required to be worn in the area
- The exit area from a controlled area shall contain appropriate contamination monitoring equipment and personal decontamination facilities
  - Equipment for monitoring for contamination of skin and clothing.
  - Equipment for monitoring for contamination of any object or material being removed from the area.
  - Washing or showering facilities for radioactive decontamination.
  - Suitable storage for contaminated protective clothing and equipment

- Work clearly segregated from non-radioactive work
- High standard of cleanliness
- Monitor for contamination
- Protective clothing and gloves
- No mouth pipetting
- Items removed from DRA must be monitored
- Clear labelling of radioactive materials
- Use fume cupboards or glove boxes
- Special waste receptacles
- Monitoring of personnel prior to exit
- Separate cleaning equipment
- Electrical heating only
- No food or drink in DRA
- Separate laundering for protective clothing
- No glass-blowing
- + 8 recommended work practices

5 – Storage and Transport

- Radioactive materials shall be used and stored so that they do not present a hazard to persons in the vicinity, and are secure against theft or unauthorized tampering
- The store shall meet the security requirements pertaining to the assessed security category
- Radioactive materials shall be stored in a dedicated radioactive source store, separate from other dangerous goods
  - Easily decontaminated
  - Adequately shielded
  - Radiation warning sign at entrance
  - Sufficient air exchange
  - All containers labelled

- Transport of radioactive materials in Australia is controlled by territory, state, Commonwealth and international regulations, and shall be in accordance with the *Code for the Safe Transport of Radioactive Material* (2014)
- Transport of radioactive materials into or within New Zealand is controlled by radiation safety regulations, and shall be in accordance with the IAEA, *Regulations for the Safe Transport of Radioactive Material*
- A radiation management plan shall contain detailed procedures for the transport of each radioactive material regularly consigned from the laboratory.

6 – Monitoring Ionizing Radiation

- The responsible person shall ensure that a radiation monitoring program is developed and maintained, as required by the appropriate regulatory authority
- The purpose of a radiation monitoring program shall be to:
  - enable assessments to be made of the exposure of laboratory workers and members of the public (if appropriate) to ionizing radiation;
  - permit timely detection of changes in radiation parameters which could lead to increased exposures; and
  - produce sufficient information for optimization purposes

Monitoring includes:

- the measurement of doses received by laboratory workers and members of the public;
- the measurement of external dose rates in the laboratory;
- assessing the amount of radioactive contamination on surfaces and articles in the laboratory;
- assessing the amount of radioactive contamination in the air and in effluents; and
- measurement of dose rates external to the laboratory

7 – Radiation Incidents

Legislation or regulations may provide a different definition of a radiation incident or accident; such incidents shall be reported to the regulator.

For the purpose of this Standard, a radiation incident shall be any of the following events:

- Unplanned, short-term exposure, suspected or confirmed, of a person to external radiation greater than one-fifth of the relevant annual dose limit
- Radioactive contamination on a person or clothing exceeding 50 derived working levels (DWL)
- An intake of radioactive materials greater than one fifth of the relevant annual limit on intake (ALI)
- A spillage of an unsealed radioactive material in excess of 20 ALI (ingestion)
- Significant damage to the room (or its contents) in which radioactive materials or ionizing apparatus are used or stored.
- Loss of, or damage to, a sealed source or its container, or loss of more than 20 ALI (inhalation) of an unsealed radioactive material.

8 – Management of Radioactive Wastes

Legislation establishes requirements for the safe management of radioactive waste prior to its disposal

Disposal of radioactive waste shall be effected only in accordance with appropriate radiation and other waste disposal legislation:

- after consultation with the RPA
- after the required approvals have been granted

A – Dose Limits

The objective of this Appendix is to outline the system of radiation protection recommended by the ICRP and to define the dose limits that apply in various situations.

The radiation doses received as a result of work with radioactive materials or irradiating apparatus shall not exceed the limits set by the relevant legislation:

- National Directory for Radiation Protection (Australia)
- Schedule 3 of the Radiation Safety Act 2016 (New Zealand)

B – Derived Radiation Protection Quantities

DERIVED WORKING LEVELS FOR SURFACE CONTAMINATION (Bq/cm^2)				
Radiotoxicity group	**Maximum level within laboratory**		**Maximum level on skin or items leaving the laboratory**	
	α emitters	non-α emitters	α emitters	non-α emitters
Group 1	0.1	1	0.05	0.5
Group 2	1	10	0.1	1
Group 3	10	100	1	10
Group 4	100	1000	10	100

OCCUPANCY AND DESIGN FACTORS		
Place of occupancy	**Occupancy, hours per year**	**Maximum dose rate, µSv per hour**
Work areas, laboratories, offices, darkrooms, occupied rooms in adjacent buildings	2000	0.5
Utility rooms	100	10
Unattended parking areas, unattended waiting rooms, corridors, stairways, automatic lifts, pathways, roadways	50	20

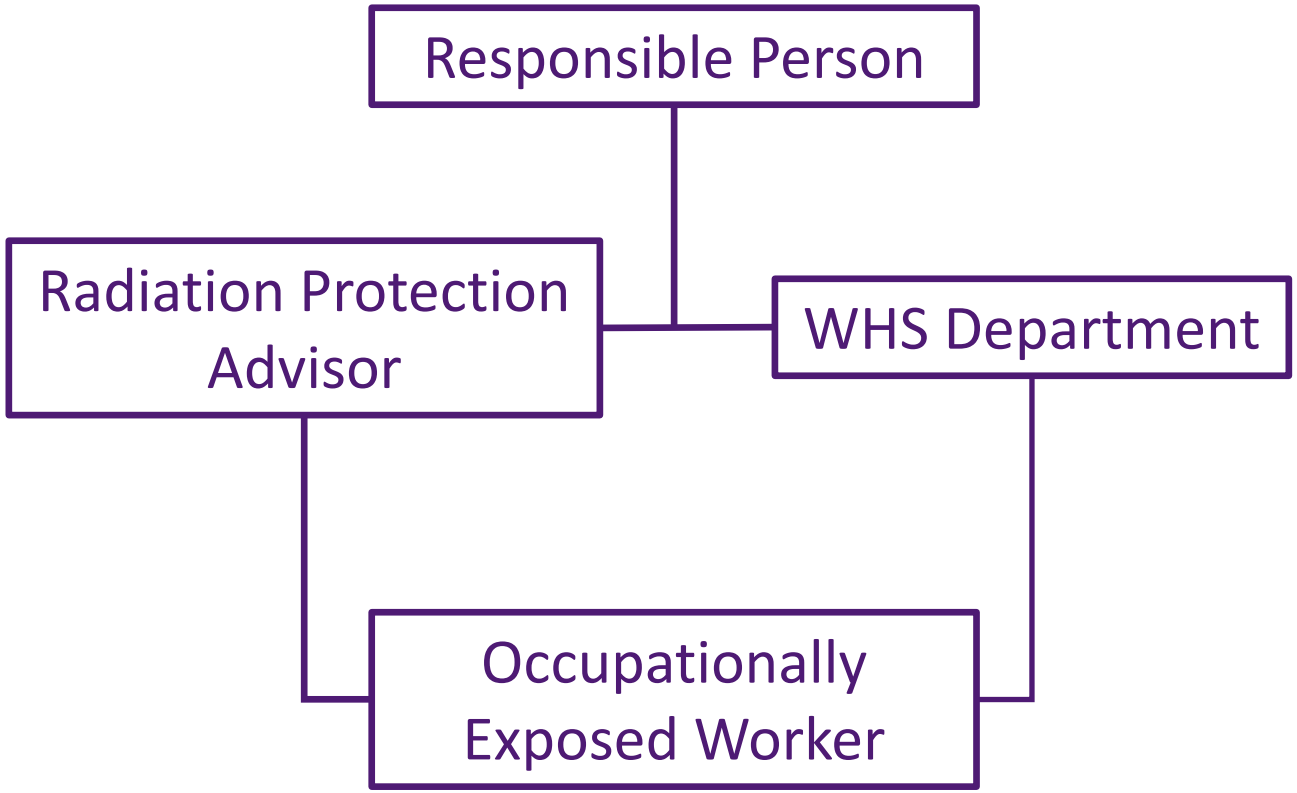
Introduces

- Annual Limit on Intake (ALI)
- Derived Air Concentration (DAC)

C – Roles and Responsibilities

Informative appendix - only for information and guidance

- Responsible Person
- Radiation Protection Advisor
- Occupationally Exposed Worker
- Non-occupationally exposed person
  - Member of the public
  - Pregnant or breast-feeding
  - Young person



D – Measurement of Ionizing Radiations

The monitoring of ionizing radiation is a key element in providing assurance that doses do not exceed the relevant dose limits and that protection and safety measures have been optimized.

- Instrument quality assurance
- Instrument selection
- Personal Monitoring
  - External Dose
  - Internal Dose
- Source monitoring
- Workplace monitoring
  - Surface contamination
  - Airborne contamination
  - Contaminated liquids
- Environmental monitoring

E – Ionizing Radiation Symbols

Personal Radiation Monitoring

Purpose

- Provide evidence that Dose Limits are not exceeded
- Provide records of occupational exposure
- Provide data for dose optimisation

Dose Limits and Dose Constraints

Dose Limit

- Defined value
- prevent radiation-induced tissue reactions
- limit the probability of radiation-related probabilistic effects to an acceptable level
- apply to regulated sources only
- If exceeded
  - Non-compliance with regulatory requirements
  - Requires formal investigation
  - Will result in changes to work practices

Dose Constraint

- A prospective, source related value
- considers the estimated individual dose distribution
- below which protection is optimised for a given source.
- applied in a planned exposure situation
- If exceeded:
  - does not represent non-compliance with regulatory requirements
  - Should be investigated to improve procedures
  - May result in changes to work practices

External Dose Monitoring

Electronic vs Passive Dosemeters

Electronic Dosemeters

- Pros
  - Dose displayed in real-time
  - Alarm settings
  - Instantaneous dose and dose rate
- Cons
  - Requires some expertise to use
  - Expensive
  - Regular maintenance

Passive Dosemeters

- Pros
  - Cheap
  - Lightweight
  - Easy to use
- Cons
  - Wait for dose results
  - Cumulative dose
  - No alarm

Approval for Use

ISO 4037-3:2019

Radiological protection

X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy

Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence

IEC 62387:2020

Radiation protection instrumentation - Dosimetry systems with integrating passive detectors for individual, workplace and environmental monitoring of photon and beta radiation

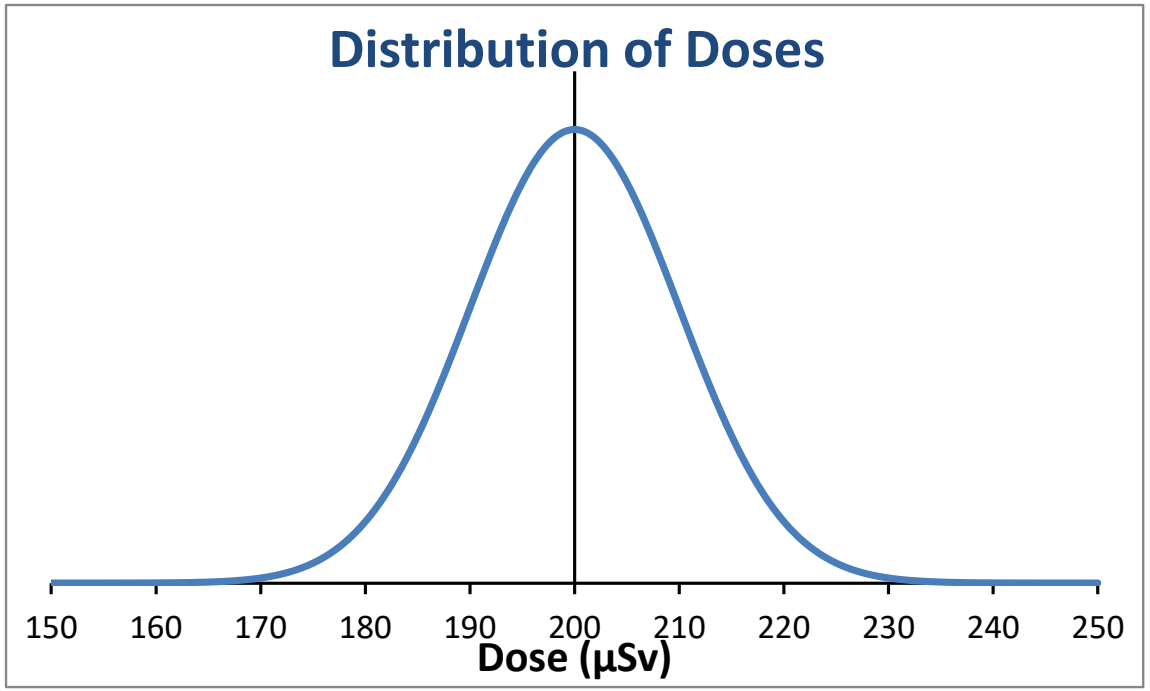
ISO/IEC 17025:2017

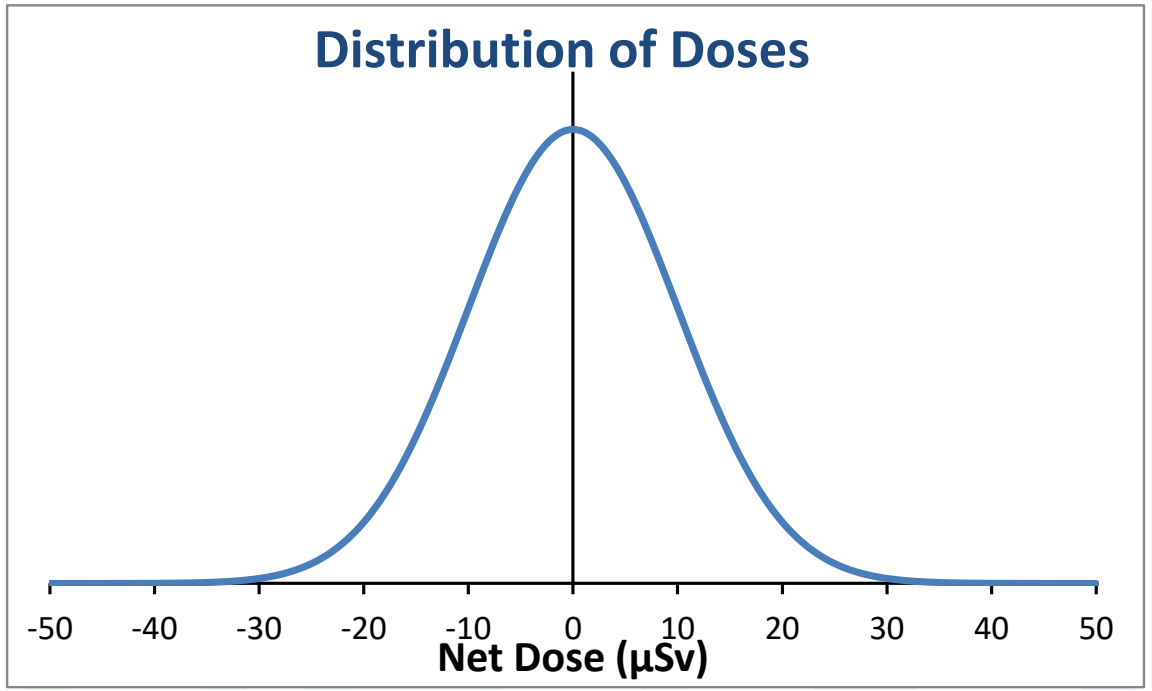
General requirements for the competence of testing and calibration laboratories

Occupational Dose

Occupational Dose = Measured Dose – Background Dose

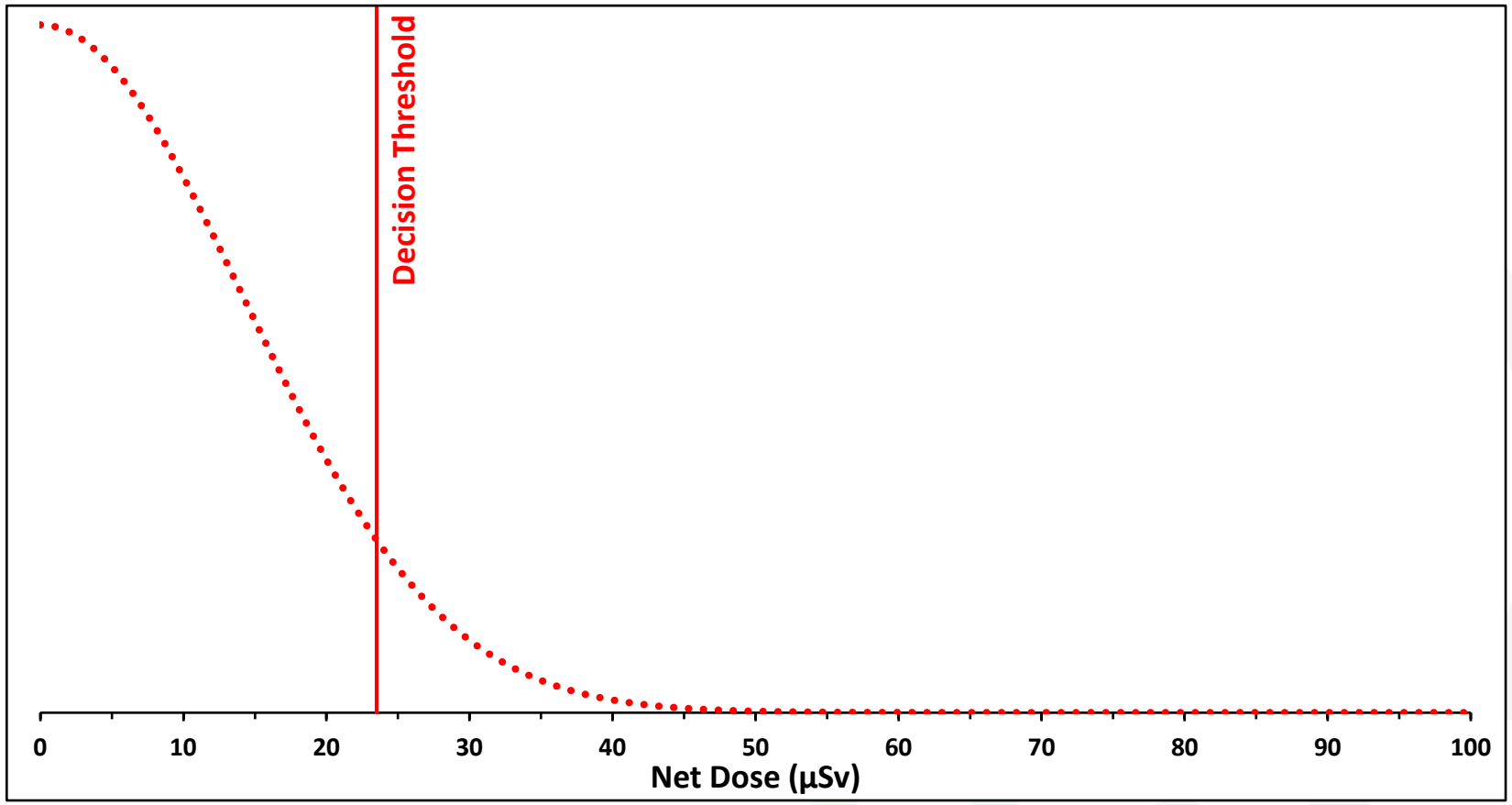
Measurement of Occupational Dose





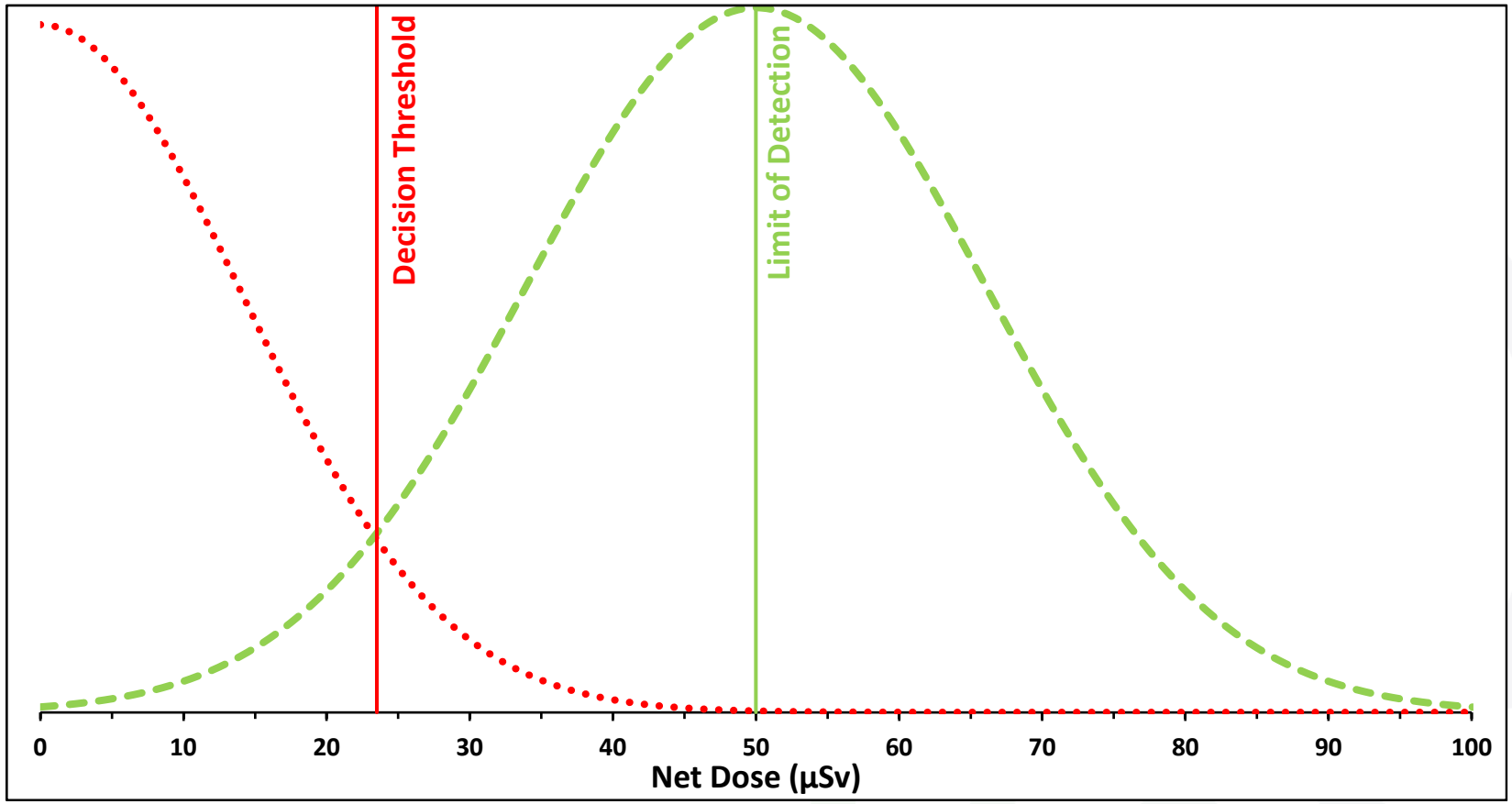
Characteristic Limits

Decision Threshold - Detect an occupational dose with statistical certainty?



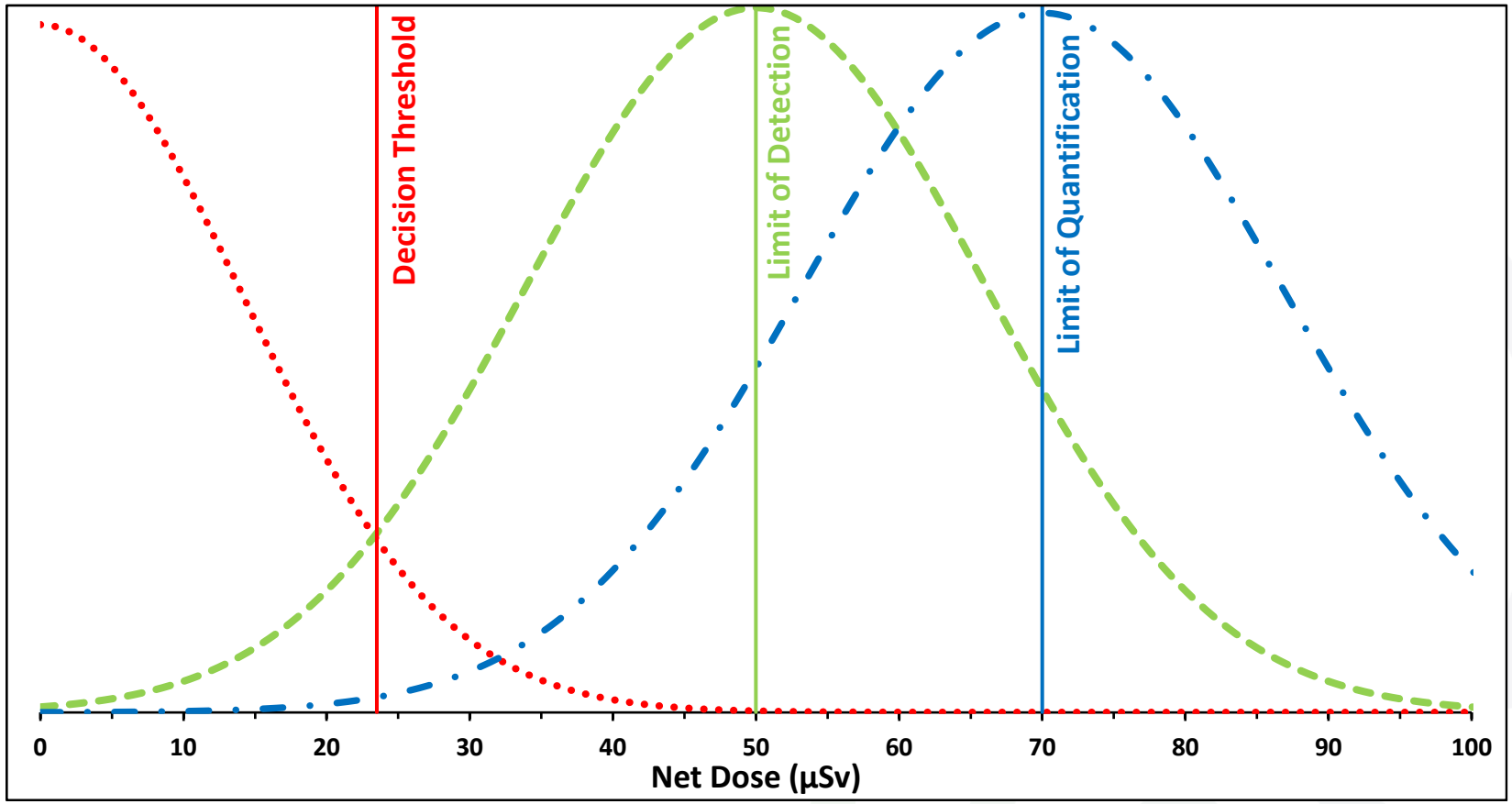
Characteristic Limits

Detection Limit - Quantify an occupational dose with statistical certainty?

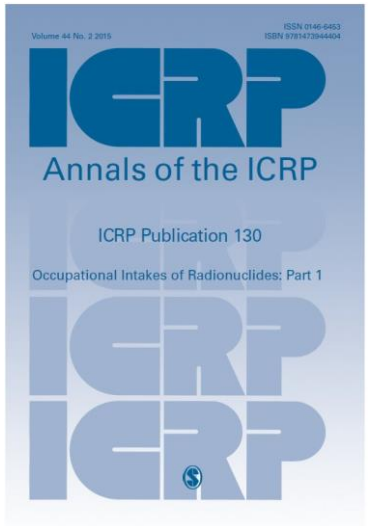


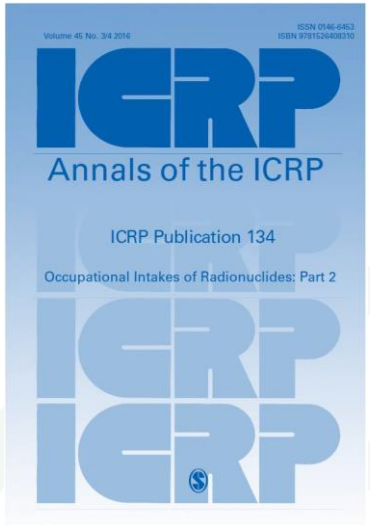
Characteristic Limits

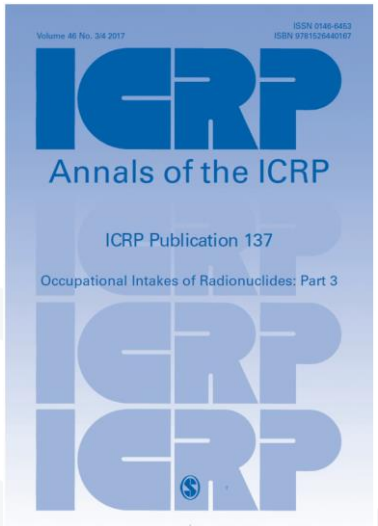
Quantification Limit - Quantify an occupational dose with an acceptable confidence interval?

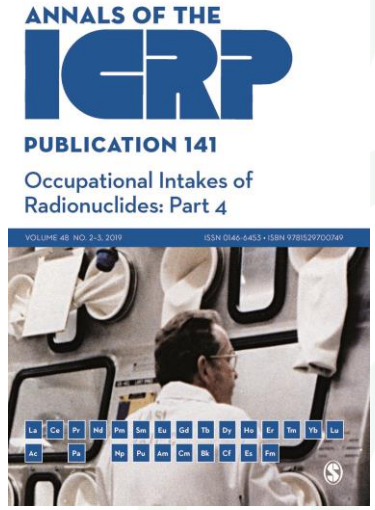


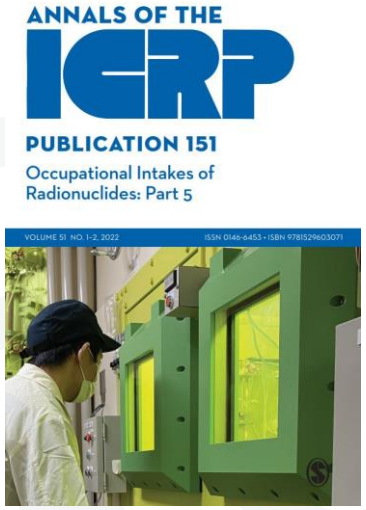
Internal Dose Assessment



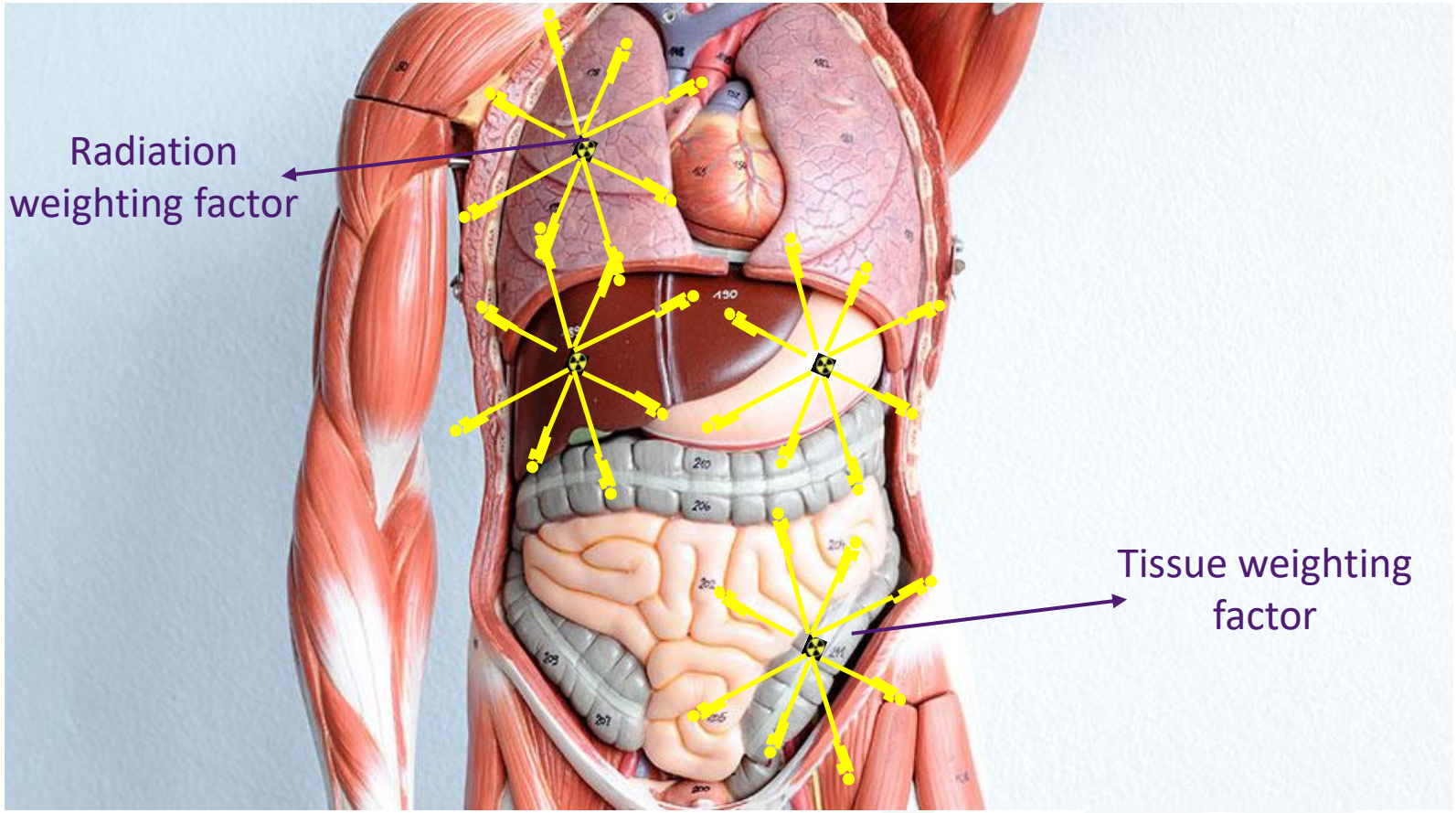








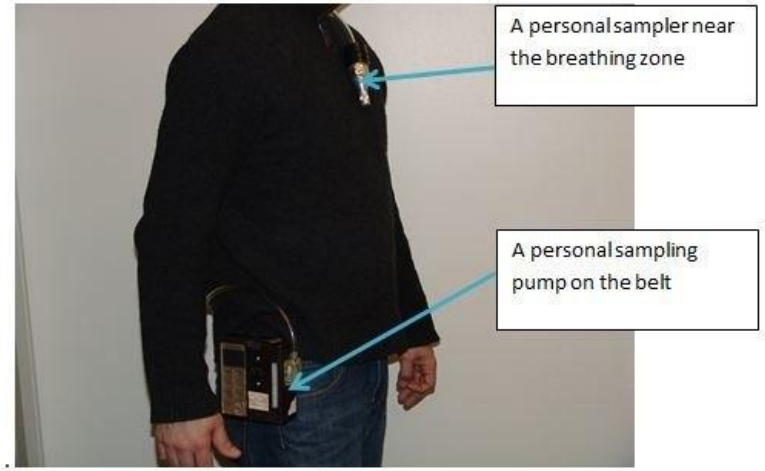
Radiological Considerations



Biological Considerations

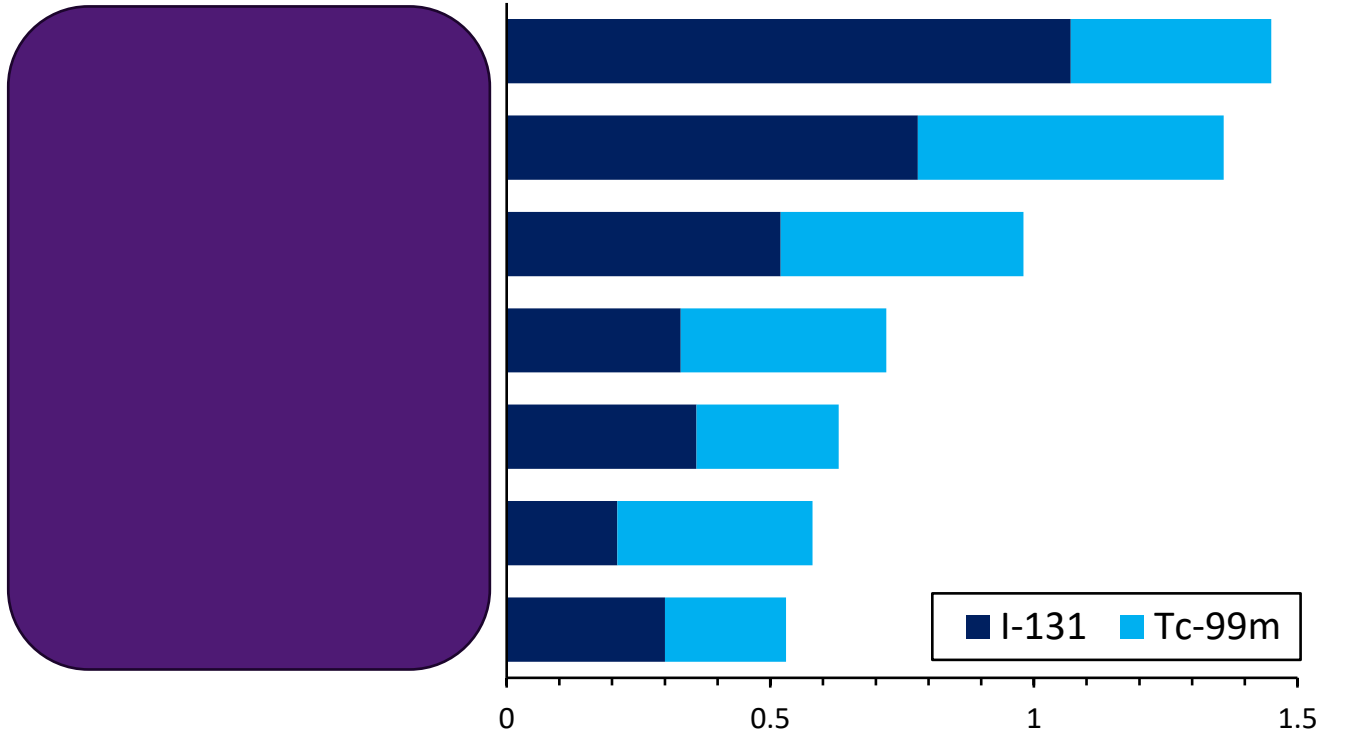
- Radionuclides are just chemical elements
- Some elements are more easily incorporated than others
- Some elements may go to specific organs
- Elements pass through the body at different rates
- Biological Half-life
  - Affected by site of administration
  - May be shortened by administering other substances

Dose Assay


A personal sampler near the breathing zone
A personal sampling pump on the belt

Why Bother?

- Radiotherapy Centre
  - Measure Thyroid
    - Hot Lab Workers
    - Radiochemists
    - Imaging Assistants
    - Nurses and Assistant Nurses
    - Physicians and Physicists
    - Housekeepers/Cleaners
    - Technologists



Estimation of Internal Radiation Dose to Nuclear Medicine Workers at Siriraj Hospital
Thai Medical Physicist Society and Faculty of Allied Health Sciences
6th Annual Scientific Meeting, Phitsanulok, Thailand

Group Discussion

Thank you

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SOUTH PACIFIC ENVIRONMENTAL RADIOACTIVITY ASSOCIATION

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