Safe Radiation Practices - Ionising
It is expected that at the end of this training session participants will be able to verify understanding of the performance criteria outlined in:

– Safe Radiation Practices – Ionising
Ionising Radiation Requirements
  – Legal Requirements
  – University of Melbourne Requirements
  – Ionising Radiation
  – Biological effects and Potential Exposures
  – Ionising Radiation Protection Principles
  – Identification and Storage
  – Monitoring Equipment
  – Incidents and Emergencies
  – Radioactive Waste Management
  – Supervisor/Manager Responsibilities
  – Laboratory Certification

Assessment
Commonwealth Legislation

- Australian Radiation Protection and Nuclear Safety Act 1998
- Australian Radiation Protection and Nuclear Safety Regulations 1999
- Nuclear Non-Proliferation (Safeguards) Act 1987

Victorian Legislation

- Radiation Act 2005
- Radiation Regulations 2007
- Occupational Health and Safety Act 2004
- Occupational Health and Safety Regulations 2007
Legal Requirements

Advisory Bodies

- The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
  - Radiation Protection Series (RPS)
  - Radiation Health Series (RHS)

- Standards Australia
  - AS 2243.4 Safety in laboratories. Part 4. Ionizing Radiations
University Policy and Procedure
• Ionising Radiation Risk Management Procedure
• Ionising Radiation Management Plan

University Licensing Requirements
• University of Melbourne Radiation Management Licence
• Use Licences

Roles and responsibilities
• Manager/Supervisor
• University of Melbourne Radiation Safety Advisor (RSA)
• Departmental Radiation Safety Officer (DRSO)
• Personnel (staff, students and others)

Electromagnetic Radiation Safety Committee
• Twelve members representing both ionising and non-ionising radiation
• Provides guidance and recommendations
Defining Ionising Radiation

- Ionising radiation consists of highly energetic particles or electromagnetic waves that can detach electrons from atoms or molecules, thus ionising them.

GAEC (2009)
Types of Ionising Radiation – Electromagnetic

United States Environmental Protection Agency (2011)
Types of Ionising Radiation – Particulate

- Electron
- Alpha particle
- Neutron

Helium Atom
Penetration Properties

Ionising Radiation

< Varying Density >
Measuring Radiation – Activity

Activity is measured in becquerel (Bq)

A becquerel is defined as:

- One disintegration per second (1Bq = 1dps)
- 60 counts per minute (60 cpm)

<table>
<thead>
<tr>
<th>Curies Ci</th>
<th>Becquerel Bq</th>
<th>dps</th>
<th>cpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$37 \times 10^9$ ($3.7 \times 10^{10}$)</td>
<td>$3.7 \times 10^{10}$</td>
<td>$2.22 \times 10^{12}$</td>
</tr>
<tr>
<td>0.1 (100 mCi)</td>
<td>$3.7 \times 10^9$</td>
<td>$3.7 \times 10^9$</td>
<td>$2.22 \times 10^{11}$</td>
</tr>
<tr>
<td>0.01 (10 mCi)</td>
<td>$3.7 \times 10^8$</td>
<td>$3.7 \times 10^8$</td>
<td>$2.22 \times 10^{10}$</td>
</tr>
<tr>
<td>0.001 (1 mCi)</td>
<td>$3.7 \times 10^7$</td>
<td>$3.7 \times 10^7$</td>
<td>$2.22 \times 10^9$</td>
</tr>
<tr>
<td>0.0001 (100 μCi)</td>
<td>$3.7 \times 10^6$</td>
<td>$3.7 \times 10^6$</td>
<td>$2.22 \times 10^8$</td>
</tr>
</tbody>
</table>
Measuring Radiation – Energy

The unit of measurement of ionising radiation energy is the **electron volt** (eV).

An electron volt is the kinetic energy gained by an electron passing through a potential difference of one volt.

An electron volt (eV) is a unit used to measure the energy of ionising radiation.

\[ 1 \text{ eV} = 1.602 \times 10^{-19} \text{ Joule (J)} \]

Electron volts are normally expressed in keV or MeV.
Measuring Radiation

Absorbed Dose (Gy)
Absorbed dose will be the amount of energy deposited into a material by ionising radiation.

Equivalent Dose (Sv)
The equivalent dose evaluates the likelihood of harm from the absorbed dose on a biological tissue (humans).

\[ H = D \times W_R \]

- \( H \) = equivalent dose
- \( D \) = average absorbed dose in organ
- \( W_R \) = radiation weighting factor
Ionising Radiation

Measuring Radiation – Effective Dose (Sv)

Different organs/tissues in the human body will have varying degrees of sensitivity to ionising radiation.

The effective dose evaluates the equivalent dose on a specific biological organ/tissue.

\[ E = H \times W_T \]

- \( E \) = effective dose
- \( H \) = equivalent dose
- \( W_T \) = tissue weighting factor
Ionising Radiation

Measuring Radiation – Biological Unit Summary

Absorbed Dose \( D = \text{J/kg} \)

Equivalent Dose \( H = D \times W_R \)

Effective Dose \( E = H \times W_T \)

When you read Sv (unless stated) assume it to mean effective dose
Radioactive Decay

Radioactive decay is the process where an isotope with an unstable nucleus undergoes spontaneous transformation resulting in new elements and/or isotopes with emissions of ionising radiation.
Radioactive Decay – Half-life

Radiological half-life is the time required for a radionuclide, or radioactive isotope, to decay to one-half its original activity.

\[ A = A_0 \frac{t}{T_{1/2}} \]
\[ = A_0 e^{-\frac{0.693 t}{T_{1/2}}} \]

Amount of radioactive material \( A \) compared to the original amount \( A_0 \) or any quantity which is proportional to \( A \).

Time as a multiple of the halflife \( T \)

HyperPhysics (2010)
Background Radiation
Radiation that is continuously present in the environment.

ARPANSA (2008)
Dose Limits

<table>
<thead>
<tr>
<th>Application</th>
<th>Occupational Dose Limit</th>
<th>Public Dose Limit</th>
<th>UoM Dose Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>effective dose</td>
<td>20 mSv per year, averaged over a period of 5 consecutive calendar years</td>
<td>1 mSv in a year</td>
<td>1 mSv in a year</td>
</tr>
<tr>
<td>lens of the eye</td>
<td>150 mSv</td>
<td>15 mSv</td>
<td>15 mSv</td>
</tr>
<tr>
<td>skin</td>
<td>500 mSv</td>
<td>50 mSv</td>
<td>50 mSv</td>
</tr>
<tr>
<td>hands and feet</td>
<td>500 mSv</td>
<td></td>
<td>50 mSv</td>
</tr>
</tbody>
</table>

The effective dose limit at the University of Melbourne is to that of a member of the public 1 mSv annually.
Cell and Tissue Damage

- cell death
- free radicals
- chromosomal aberrations
- mutations
- genomic instability

Cell image from Baran (2010)
Routes of Exposure
Radiation hazards are divided into two classes

External Exposure

Internal Exposure
- Inhalation
- Ingestion
- Iodine - 131 (Beta Particles)
  Thyroid
- Cesium - 137 (Gamma Rays)
  Muscle and Soft Tissue
- Plutonium - 239 (Alpha Particles)
  Lung
  Liver
  Bone

Tritrain (2011)
Three Principles of Radiation Management

- **Justification**
- **Limitation**
- **Optimisation**

**ALARA - As Low As Reasonably Achievable**

ICRP (2007)
Controls to Prevent External Exposure - Time

The dose accumulated by a person working in an area with a particular dose rate is directly proportional to the amount of time spent in the area.
Controls to Prevent External Exposure – Distance

The General Inverse Square Law

X-rays, Gamma rays and Neutrons, obey the general inverse square law.

The energy twice as far from the source is spread over four times the area, hence one-fourth the intensity.

HyperPhysics (2010)
Controls to Prevent External Exposure – Shielding

A thin sheet of paper will shield alpha particles

Perspex can be used to shield beta particles

Lead can be used to shield x-rays and gamma rays
Controls to Prevent External Exposure – Shielding Gamma/X-Ray

**Half-value Layer (HVL)**
The thickness of a material that will reduce the intensity of the beam by half.

**Tenth Value Layer (TVL)**
The thickness of a material that will reduce the intensity of the beam by a factor of 10.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Mean Energy</th>
<th>Half-life</th>
<th>HVL Pb (mm)</th>
<th>TVL Pb (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{60}$Co</td>
<td>1.25 MeV</td>
<td>5.26 years</td>
<td>11</td>
<td>33.9</td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td>1.03 MeV</td>
<td>1,626 years</td>
<td>16</td>
<td>28.9</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>662 keV</td>
<td>30 years</td>
<td>6.5</td>
<td>18.5</td>
</tr>
<tr>
<td>$^{192}$Ir</td>
<td>360 keV</td>
<td>74.2 days</td>
<td>3.1</td>
<td>7.1</td>
</tr>
<tr>
<td>$^{222}$Rn</td>
<td>1.03 keV</td>
<td>3.83 days</td>
<td>1.6</td>
<td>2.9</td>
</tr>
<tr>
<td>$^{198}$Au</td>
<td>412 keV</td>
<td>2.7 days</td>
<td>3.3</td>
<td>8.9</td>
</tr>
<tr>
<td>$^{125}$I</td>
<td>28 keV</td>
<td>59 days</td>
<td>0.025</td>
<td>0.38</td>
</tr>
<tr>
<td>$^{103}$Pd</td>
<td>22 keV</td>
<td>17 days</td>
<td>0.013</td>
<td>0.21</td>
</tr>
<tr>
<td>$^{169}$Yb</td>
<td>93 keV</td>
<td>32 days</td>
<td>1.6</td>
<td>3.1</td>
</tr>
</tbody>
</table>
Controls to Prevent Internal Exposure

Contain

Clean

Minimise
Case Study

Activity of source 7,000,000,000,000 Bq

Time taken to remove source = 7 hours

Absorbed dose by workers over seven hours = 14 μSv

Absorbed dose by workers flying from Sydney to Melbourne to do the operation = 7 μSv
Effective Control of your ionizing radiation environment depends on your:

Knowledge

Skill and Experience

Work practices
Identification Requirements

The purpose of identification is to ensure that the radioactive material is known.

Many radioactive materials also have associated chemical properties.
Storage Requirements

Storage arrangements should include an assessment of the level of risk associated with the use of the radioactive material.

Storage requirements for radioactive materials must also take into account both the chemical properties and the radioactive properties.
Radiation Monitors

Thermoluminescent Dosimetry Monitor (TLD)
- red monitor detects beta particles and gamma/x-rays
- blue monitor detects neutron particles and gamma/x-rays

Real time neutron/gamma monitor

Real time beta/gamma monitor
Meters

- **Survey meter** for dose monitoring – monitors biological risk
  Need to be calibrated annually by a registered company

- **Contamination meter** used for monitoring the environment
  Need to be checked weekly against a known source
Incident and Emergency Procedures

Local Area Emergency Response – Practical Considerations

- The local area should have documented emergency procedures.
- If an incident occurs take time to implement the emergency procedure.
- If you think you are contaminated, don’t leave the room but rather get assistance from others.
- Let other people in the area know what has happened
- Restrict access to the area.

You, your colleagues and the DRSO now have time to sit down and discuss the best way forward to deal with the incident.
# University Requirements

<table>
<thead>
<tr>
<th>Disposal Method</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilution and dispersion</td>
<td>$^{14}\text{C}$</td>
</tr>
<tr>
<td></td>
<td>When diluted to non-radioactive levels $^{14}\text{C}$ is disposed of through the UoM EPA waste contractor.</td>
</tr>
<tr>
<td></td>
<td>$^{3}\text{H}$</td>
</tr>
<tr>
<td></td>
<td>When diluted to non-radioactive levels $^{3}\text{H}$ can be emptied down the sink.</td>
</tr>
<tr>
<td>Delay and decay</td>
<td>$^{32}\text{P}$ and $^{33}\text{P}$</td>
</tr>
<tr>
<td></td>
<td>$^{32}\text{P}$ and $^{33}\text{P}$ can be stored at the local area until they have decayed to a non-radiological level.</td>
</tr>
<tr>
<td></td>
<td>Length of decay will depend on both the half-life and the activity.</td>
</tr>
<tr>
<td>Concentration and containment</td>
<td>$^{137}\text{Cs}$</td>
</tr>
<tr>
<td></td>
<td>$^{137}\text{Cs}$ has a half-life of 30 years and is stored in an appropriately built location.</td>
</tr>
</tbody>
</table>
Induction and training requirements

- Local area induction
- Training applicable to the work

Risk assessment for all ionising radiation activities

- Identify the hazards
- Evaluate the risk
- Determine the controls
- Review the risk assessment

Hierarchy of Control
- Elimination
- Substitution
- Engineering
- Administrative
- Personal Protective Equipment (PPE)
Supervisor/Manager Responsibilities

- Standard Operating procedures
- Purchasing
- Transport
Purpose of Certification is to ensure a laboratory
• complies with legal requirements
• complies with UoM requirements
• undertakes ionising radiation activities in a manner that is without risks to health and safety
Advice and Assistance

• Department Radiation Safety Officer (DRSO)
  http://safety.unimelb.edu.au/topics/radiation/drso/

• Common Services, Occupational Health and Safety radiation advice email
  radiation-info@unimelb.edu.au

• University of Melbourne Radiation Safety Advisor (UoM RSA)
  http://safety.unimelb.edu.au/about/contacts/common_chancellery.html#advice
Radiation

New guidance materials are gradually being added to this page. Existing items may be reorganised as more material is added.

On this page:

- Introduction to Electromagnetic Radiation Management
- Procedures and Guidance Materials
- Committees and Groups
- Radiation Safety Certification Program
- Training
- More Information and Assistance

Introduction to Electromagnetic Radiation Management

Electromagnetic radiation is used in a variety of teaching and research areas throughout the University. Some types of electromagnetic radiation can affect people's health and cause damage to property or the environment.

Types of electromagnetic radiation used at the University include:

- Ionising Radiation, such as:
  - open sources
  - closed sources

http://safety.unimelb.edu.au/topics/radiation/