Radiation Safety Training
(Nuclear Radiation)

Presented by:
Human Resources
Occupational Health and Safety
Radiation Safety Coordinator
**Mission:** We enable the learning of safe work behaviour. We do this by providing opportunities for individuals to learn the knowledge and skills to take personal ownership of their health and safety.

**Vision:** Our vision is the use of safe work behaviour as a life skill.

**Website:** http://www.uwo.ca/humanresources
Bill C-45 establishes criminal liability for organizations and individuals when they fail to take reasonable steps to prevent workplace accidents that affect workers or the general public—conviction will result in a criminal record.

Key Elements

- The legal duty is similar to the general duty clauses currently found in the Occupational Health and Safety Act of Ontario. However, it elevates the penalty to the status of a crime with a permanent criminal record.
Bill C-45 - Criminal Legislation affecting Workplace Safety

(continued)

• It applies to “everyone who undertakes, or has the authority, to direct how another person does work or performs a task...”. Bill C-45 extends legal duties to a new level that could potentially apply from a co-worker up to the president.

• The requirement “to prevent bodily harm to that person, or any other person, arising from that work or task” goes farther than any current OH&S legislation in Canada. Bill C-45 casts the net to include all employees as well as the public that may be affected by the work or task.
An effective program with demonstrated clear communication helps not only to ensure compliance but helps to ensure the health and safety of employees.

The first line of defence against death and injury in the workplace remains an organization’s and an individual’s proactive compliance with the existing workplace health and safety regulations.
Human Resources
Occupational Health & Safety - Programs

- Biosafety
- Construction and Facility Safety
- Laboratory and Environmental Safety
- Radiation Safety
- Laser Safety
- X-ray Safety
Training Objective

• Understand radiation physics, radiation protection, radiation detection and measurement
• Describe biological effects of radiation
• Recognize the requirements of transportation and receipt of nuclear substances
• Know your responsibilities to work safely
• Know the radiological emergency response
An Overview Of Radiation Safety Program
Regulatory Requirements

- Nuclear Safety and Control Act (NSCA)
- Canadian Nuclear Safety Commission (CNSC) Regulations and Licensing
  - Obligations of Licensees
  - Obligations of Workers
UWO Licences
Issued by the CNSC

1. Consolidated Nuclear Substances and Radiation Devices
2. Operating Tandetron Accelerator
3. Servicing Tandetron Accelerator
4. Import Tritium (Hydrogen 3)
UWO Mandate

• Comply with NSCA, CNSC regulations and licences issued to UWO

• Keep radiation exposures to ALARA (As Low As Reasonably Achievable) by:
  • Management control over work practices
  • Personnel qualification and training
  • Control of occupational and public exposure to radiation
  • Planning for emergency or unusual situations
  • Ascertain the quantity and concentration of any nuclear substance released as a result of the licensed activity
Program Structure

1. User
2. Permit Holder
3. Radiation Safety Coordinator
4. Senior Management
5. Radiation Safety Committee
Permit Holder & User’s Requirements

• Complete the UWO safety training program:
  • General radiation safety training. Refresher is required every three years (available on OWL)
  • Specific radiation safety training on topic, procedure or equipment

• Have a radiation internal permit or work under a radiation internal permit

• Provide radiation safety awareness (available on HR web site) to visitors or persons (not listed on the permit) who enter a designated radiation room and keep a record
Specific Training Record

Name: _______________________________ Date: ______________

Supervisor: __________________________

Course: ______________________________

Instructor: ____________________________

List all aspects of your daily work that are relevant to the topics covered in this training session. Specific training must be provided by your supervisor for those aspects of your job that are not covered.

<table>
<thead>
<tr>
<th>Relevant Topic, Procedure Or Equipment</th>
<th>Comments</th>
<th>Date Completed</th>
<th>Specific Training Received (Employee Initials)</th>
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Please submit to your supervisor for their records.

Signature of Supervisor ____________________________ Signature of Trainee ____________________________ Date: ______________
<table>
<thead>
<tr>
<th>Name</th>
<th>Employer or Institution</th>
<th>Supervisor</th>
<th>Work or Home Address</th>
<th>Work or Home Phone Number</th>
<th>Date</th>
<th>Attendee’s Signature</th>
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Permit Holder & User’s Requirements (cont.)

- Designated as a Nuclear Energy Worker (NEW)
- Wear required dosimeters and participate in a required bioassay program
- Be familiar with the UWO Radiation Safety Manual (available on HR web site)
- Pregnant NEW must inform her Permit Holder and Radiation Safety Coordinator as soon as she is aware of her condition
Compliance Inspection & Enforcement

- All designated radiation rooms are inspected at least once a year
- Compliance inspection checklist is available on Human Resources web site under documents & forms
- Discipline action is in place for both major and minor non-compliance issues
  - Major non-compliance issues must be corrected immediately (e.g. food/drink/utensil in a nuclear substance room)
  - Minor non-compliance issues would be an infraction which poses no immediate risk or to health, safety, security and environment (e.g. current permit not posted)
The Atom
Structure Of Matter

• The Atom: \( A = Z + N \)
  • \( A \) is the mass number
  • \( Z \) (atomic number) is the number of protons
  • \( N \) is the number of neutrons
  • For example: Carbon has 6 protons and 6 neutrons to give a mass: \( A = 6 + 6 = 12 \). Referred to as C-12
• **Isotope**: same atomic number (Z), but a different number of neutrons, and thus mass number (A)
  • Example: $^{12}$C and $^{13}$C are stable isotopes of Carbon

• **Radioisotope or Nuclear Substance**: an unstable nucleus will undergo a spontaneous transformation into a more stable decay product
  • Example: $^{14}$C is a radioisotope of Carbon
Radiation & Radioactivity
What Is Radiation?

- Radiation is energy traveling in the form of waves or particles.
- Ionizing radiation including nuclear radiation: has enough energy to remove one or more electrons of an atom, results in creation of positively charged atom and a free electron which are known as an ion pairs. Energy unit is keV or MeV.
Radiation Sources

• Background radiation is present on earth, water, air and soil. Examples include: Potassium 40, Uranium 238, etc.

• Artificial radiation is other than background radiation. Examples include: Phosphorus 32, Iodine 131, X-ray, etc.
Total Radiation Exposures

**Radiation Sources**

- **Radon**: 55%
- **Cosmic**: 8%
- **Terrestrial**: 8%
- **Internal Emitters**: 11%
- **Man-Made**: 18%

Based on an average annual effective dose equivalent of 3.6 mSv (360 mrem) and a ground level radon concentration of about 40 Bqm$^3$ (1 pCi/l)

**Man-Made Sources**

- **Medical X-Rays**: 58%
- **Nuclear Medicine**: 21%
- **Consumer Products**: 16%
- **Other**: 5%

Based on an average annual effective dose equivalent of 3.6 mSv (360 mrem) and a ground level radon concentration of about 40 Bqm$^3$ (1 pCi/l)
Alpha Particles

- Don’t travel very far and not penetrating
- Shielding with outer layer of skin
- Harmless on the outside of the body
- Toxic and harmful inside of the body due to its high energy and large particles deposited in living tissue.
Decay Scheme Of Radium-226

226 Ra → 222 Rn

α 4.785 MeV (94.4%)
α 4.602 MeV (5.5%)
γ 0.186 MeV (3.3%)
Negative Beta Particles

- Negative charge
- Same size as electron
- Penetrating depending on the energy
- Can produce secondary X-ray bremsstrahlung radiation in dense material
- Use low Z material (plastic/wood/plexiglass) for shielding to avoid bremsstrahlung production. For example: Phosphorus 32
Decay Scheme Of Phosphorus-32

\[ ^{32}\text{P}_{15} \rightarrow ^{32}\text{S}_{16} + \beta^- \]

\[ \beta^- 1.71 \text{ MeV} \]
Positive Beta Particles
(Positron)

- Positive charge +1
- Same size as electron
- Very penetrating
- For example: Sodium 22 has positron-electron annihilation leads to gamma-pairs production (1.275 MeV). Lead is required to shield gamma-pairs radiation.
Decay Scheme Of Sodium-22

$^{22}\text{Na}_{11}$

EC 10.2%  $\rightarrow$  $\beta^+$ 0.545 MeV 89.8%

$\gamma$ 1.275 MeV 100%

$\rightarrow$

$^{22}\text{Ne}_{10}$
Types Of Radiation

Gamma ray
- Originate within the nucleus and no charge
- Waves are pure energy
- Very penetrating, high density material (Z) for shielding (lead, concrete, etc)

X-ray
- Similar to gamma ray except x-rays originate outside of the nucleus

Neutron
- Very penetrating, large amount of hydrogen required for shielding such as water, wax and concrete
Decay Scheme Of Cesium-137

$^{137}\text{Cs}_{55}$

$\beta^-$ 1.174 MeV
5%

$\beta^-$ 0.512 MeV
95%

$\gamma$ 0.662 MeV
85%

$^{137}\text{Ba}_{56}$
Radiation Penetration & Shielding

- Alpha (α)
- Beta (β)
- Gamma, X-rays (γ)
- Neutrons

Materials for Protection:
- Aluminium
- Lead
- Concrete
Radioactivity & Physical Half Life

• **Radioactivity**: The rate of decay or transformation of a nuclear substance is described by its activity
  
  • 1 microcurie ($\mu$Ci) = $2.2 \times 10^6$ disintegration per minute (dpm)
  • 1 becquerel (Bq) = 1 disintegration per second (dps)
  • 1 microcurie ($\mu$Ci) = 37,000 Bq or 37 kBq

• **Physical half life**: the amount of time required for an initial activity to be reduced by 50%
### Common Nuclear Substances

<table>
<thead>
<tr>
<th>Nuclear Substance</th>
<th>Type of Radiation</th>
<th>Physical Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine 131 (I-131)</td>
<td>Gamma &amp; Negative Beta</td>
<td>8 days</td>
</tr>
<tr>
<td>Phosphorus 32 (P-32)</td>
<td>Negative Beta</td>
<td>14 days</td>
</tr>
<tr>
<td>Iodine 125 (I-125)</td>
<td>Gamma</td>
<td>60 days</td>
</tr>
<tr>
<td>Sodium 22 (Na-22)</td>
<td>Gamma &amp; Positive Beta</td>
<td>2.6 years</td>
</tr>
<tr>
<td>Sulfur 35 (S-35)</td>
<td>Negative Beta</td>
<td>87 days</td>
</tr>
<tr>
<td>Tritium (H-3)</td>
<td>Negative Beta</td>
<td>12.3 years</td>
</tr>
<tr>
<td>Cobalt 60 (Co-60)</td>
<td>Gamma &amp; Negative Beta</td>
<td>5.27 years</td>
</tr>
<tr>
<td>Cesium 137 (Cs-137)</td>
<td>Gamma &amp; Negative Beta</td>
<td>30.17 years</td>
</tr>
<tr>
<td>Americium 241 (Am-241)</td>
<td>Alpha</td>
<td>433 years</td>
</tr>
<tr>
<td>Carbon 14 (C-14)</td>
<td>Negative Beta</td>
<td>5730 years</td>
</tr>
<tr>
<td>Technetium 99m (Tc99m)</td>
<td>Gamma &amp; Negative Beta</td>
<td>6 hours</td>
</tr>
<tr>
<td>Chromium 51 (Cr-51)</td>
<td>Gamma &amp; X-ray</td>
<td>28 days</td>
</tr>
</tbody>
</table>
Decay Calculation

• **Decay Equation**
  - \( A = A_0 \times (0.5)^{t/T_{1/2}} \)
  - \( A = \text{final activity} \)
  - \( A_0 = \text{original activity} \)
  - \( n = t/T_{1/2} = \text{number of half-lives elapsed} \)

• **Example**: P-32 has a half-life of 14 days and initial activity is 40 kBq (1.081 µCi). Find activity remaining (\( A \)) after 42 days (\( t \)).

**Solution**: \( n = t/T_{1/2} = \text{number of half-lives} = 42/14 = 3 \)
\( A = 40 \text{ kBq} \times (0.5)^3 = 5 \text{ kBq} (0.135 \mu\text{Ci}) \)
Biological & Effective Half Life

- **Biological half life**: the time required for the amount of a substance to be reduced to one half of its initial value due to elimination by biological process alone.

- **Effective half life**: the time required for a nuclear substance to be eliminated from a biological system through a combination of the physical and biological removal processes.

- For example, C-14 has an effective half life of 14 days
Basic Radiation
Dosimetry
Exposure & Absorbed Dose

- **Exposure** (Roentgen or Coulomb/kg)
  - Refers to the amount of ionization present in the air
  - Roentgen = $2.58 \times 10^{-4}$ Coulomb/kg

- **Absorbed Dose** (Gray or Rad)
  - Measure the amount of energy absorbed by a medium, body, organ or tissue
  - 1 Gray = 100 Rads = ~ 100 Roentgen
Equivalent Dose

- **Radiation Weighting Factor**: the use of relative biological effectiveness
  - Beta, gamma, X-ray = 1
  - Neutron (0.1 MeV - 2 MeV), alpha = 20
- **Equivalent Dose** (sievert or rem): this dose takes into account the biological effects of different types of radiation:
  - Equivalent Dose (Sievert) = Absorbed Dose (Gray) x Radiation Weighting Factor
  - 1 Sievert = 100 rem
Effective Dose

• The sum of weighted equivalent doses in all the organs and tissues of the body
  • Weighted effective dose (Sievert) = equivalent dose of organ or tissue (Sievert) X weighting factor
  • For example, weighting factors of thyroid gland is 0.20 and whole body is 1
Control Radiation Exposure
External Radiation Protection

- Time: direct proportional
- Distance: inverse square law
- Shielding: using appropriate shielding for different types of radiation
Gamma Cell Irradiator

- Adequate shielding
- Required radiation safety training and machine operation training
- Authorized personnel using access card and alarm system
- Required personal dosimeter and electronic dosimeter
P-32 Work Station

- Warning signs
- Proper shielding (plastic or plexiglas)
- Absorbent pads or bench top lining
- Contamination meter
- Personal Protective Equipment (PPE)
Lead Glass Shielding

- Appropriate shielding for low energy gamma emitter such as I-125
- Lead should not be used as a primary shielding for high energy beta emitter such as P-32
Tandetron Particle Accelerator

- Key control access
- Qualified and trained personnel to operate the accelerator
- Required radiation safety training and personal dosimeter (gamma & neutron)
Tandetron Particle Accelerator
Variable-Energy Positron Beam

- Key control access and alarm system
- Qualified and trained personnel to operate the beam
- Required radiation safety training and personal dosimeter
Internal Radiation Protection

• Avoid route of entry by having a good contamination control:
  • Inhalation
  • Ingestion
  • Skin absorption or entry through a wound

• Have a good contamination monitoring program
Fume hood

- Ensure the fume hood is working properly (i.e. proper face velocity – 100 fpm, sash height – max 12 inch)
- Use for working with volatile nuclear substance such as radioiodine (i.e. I-125, I-131, etc.)
Working With Unsealed Nuclear Substances

- Lab coat
- Gloves
- Safety glasses
- Appropriate shielding if required
- Personal dosimeter(s) if required
- Absorbent pads
- Contamination meter
General Safety Rules

1. Understanding the nature of your work and get specific training
2. Plan ahead to minimize time spent handling radioactivity
3. Distance yourself appropriately from the sources of radiation
4. Use appropriate shielding for radiation
5. Contain radioactive materials in defined work area
6. Wear appropriate protective clothing and dosimeters

7. Monitor the work area frequently for contamination control

8. Follow the local rules and safe ways of working

9. Minimize accumulation of waste and dispose of it properly

10. Monitor yourself, wash and monitor again after work
Radiation & Radioactivity
Measurements
• **Detector**
  • Converting the radiation energy into electrical energy

• **Meter**
  • Receiving the electrical energy from the detector then passing directly to amplifier, scaler, recorder in terms of radioactivity or radiation dose rate
Gas-filled Detector

- Ionization chamber
  - Stable, low sensitivity

- Proportional counter
  - Can discriminate between types of radiation

- Geiger Muller (GM)
  - Produces a pulse of constant amplitude regardless of the type of radiation and its energy
Gas-filled Detector

Diagram of a gas-filled detector with parts labeled:
- Radiation
- Anode
- Gas-filled chamber
- Cathode
- Resistor
- Battery
Scintillation Detector

• Solid scintillation detector
  • Very sensitive to low gamma emitter

• Liquid scintillation detector
  • Excellent for low energy beta particles (H-3) and all types of radiation
  • Detection efficiency is much higher than with other means of detection but it is more expensive
Scintillation Detector

RADIATION

LIGHT

Nal(Tl-Thallium)

OPTICAL WINDOW

ELECTRONS

PHOTOMULTIPLIER TUBE (PMT)

ANODE

OUTPUT

VOLTAGE
Exposure Monitoring

- Measuring radiation level (µrem/hr or µSv/hr) using a calibrated dose rate meter
  - Use ionization chamber or energy compensated GM. A meter must be calibrated within one year
  - The survey procedure is simple: Perform operational checks (battery, response, etc.)
  - Record the background level (e.g., 0.2 µSv/hr.)
  - Place the meter at the monitored location. Take the reading when the meter scale is stable and always record the highest reading
Ionization Chamber (left) & GM (right)

Used for measuring radiation level
Contamination Monitoring

- To measure radioactivity on the surfaces
- To reduce the risk of internal and external radiation exposure
- To detect any loss of good work practice and to assist in preventing the spread of contamination from a controlled area to uncontrolled area
• Floor plan and locations: included working and non-working surfaces
• Monitoring instruments: Use appropriate calibrated contamination instruments for nuclear substances used
• Frequency of monitoring: within seven days following handling or working with radioactive materials (as a minimum requirement)
1. Radioactive work area (Bench & Shield)
2. Floor in Front of Radioactive Waste Storage
3. Washout / Use Sink
4. Hygiene Sink
5. Refrigerator handle and door
6. Freezer handle and door
7. Telephone
8. Water Bath
9. Hybridization oven door knob and buttons
10. Floor
Potential Contaminated Equipment
Contamination Monitoring (cont.)

- Date and locations of monitoring
- Make and model of monitoring instruments
- Keep all measurement results including the print out of wiped samples, background and radioactive standard (before and after decontamination) with tester’s initials
- Monitoring records must be kept for at least three years after the last expiry date of permit
The University of Western Ontario
Unsealed Nuclear Substance Contamination Monitoring Record

Permit Holder: Hoa Ly
Room number(s): SLB 295

1. Indirect Monitoring (Wipe test using liquid scintillation counter for all types of radiation)

Liquid Scintillation Counter location: 150 MSB
Make: Beckman 5500

UWO contamination limit is 3 Bq/cm² or 900 net cpm (assuming 10% collection efficiency, 100 cm² wiped area and 50% detector efficiency as a conservative approach for most unsealed nuclear substances used) or calculated net count rate in cpm if detector efficiency is less than 50% _______________

Record results below and keep the print out from the counter in the binder.

2. Direct Monitoring (Using UWO calibrated contamination meter(s) for only P-32 and/or I-125)

Make and Model of Meter(s): Lublum Model 3/44-9
Unit (circle): cpm or cps

Net count rate(s) equal to 3 Bq/cm² (from the calibration sticker(s) for P-32 and/or I-125): 885

Direct Monitoring can be used for weekly documented contamination monitoring if radioactive work only involved P-32 and/or I-125 during that week. Record results below and Indirect Monitoring is not required.

Note: If no radioactive work for any specific week then contamination monitoring is not required. Please indicate all non-radioactive work weeks such as ANo Radioactive Work@ Do not leave blank.

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<th>Isotope used</th>
<th>Counted Unit</th>
<th>Background</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tr>
<td>1 Wk Jan</td>
<td>Jack Ball</td>
<td>H-3</td>
<td>cpm</td>
<td>40</td>
<td>23</td>
<td>46</td>
<td>23</td>
<td>64</td>
<td>34</td>
<td>21</td>
<td>39</td>
<td>34</td>
<td>53</td>
<td>79</td>
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<tr>
<td>2 Wk Jan</td>
<td>Michelle Lee</td>
<td>P-32</td>
<td>cpm</td>
<td>50</td>
<td>43</td>
<td>26</td>
<td>67</td>
<td>26</td>
<td>32</td>
<td>44</td>
<td>43</td>
<td>65</td>
<td>67</td>
<td>53</td>
</tr>
<tr>
<td>3 Wk Jan</td>
<td>No radioactive work</td>
<td>cpm</td>
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Numbered areas to be monitored indicated on the room diagram
Types Of Contamination Monitoring Instrument

- **Portable instruments or hand-held contamination instruments**
  - Thin window GM detector: suitable beta emitters (e.g. P-32)
  - NaI solid scintillation detector: suitable for gamma emitters (e.g. I-125)
- **Liquid scintillation counter (LSC)**
  - Suitable for most radiation emitters
- **Well-crystal NaI counter**
  - Mainly for gamma emitter
Detector Efficiency

1. Radiation goes directly from the radioactive material into the detector
2. Backscatter off the surface into the detector
3. Absorbed by the detector covering
4. Not detected
5. If the detector was closer, this would be detected
Use a calibrated contamination instrument

- Perform an operational checks (i.e. battery, response, etc.) and record the background count.
- Slowly passing the detector over each area marked on the floor plan at a distance of 1 cm
- If contamination is detected. Clean area and re-monitor. Record results before and after decontamination in the contamination monitoring form.
Thin Window GM Detector (left) used for P-32
Solid Scintillation Detector (right) used for I-125
Example of Direct Monitoring for P-32
Indirect Monitoring for All Nuclear Substances

Use a Liquid Scintillation Counter

- Wipe an area of 100 cm$^2$ indicated on the floor plan with dry or wet filter paper/cotton swab and put into a scintillation vial
- Add liquid scintillation fluid into wiped sample vials, close caps and count them on a wide open window (min to max energy). Blank and radioactive standards must be included with each set of wipes
- If contamination is detected. Clean area and re-monitor. Keep results before and after decontamination
Example of Indirect Monitoring (Wipe Test)
Counting Wiped Samples on Liquid Scintillation Counter
A Summary of Measurement Units

- **Radiation Level or Dose Rate (µrem/hr or µSv/hr)**
  - 1 microsievert (µSv) = 100 microrem (µrem)

- **Radioactivity Count Rate (cpm or cps)**
  - Net Count Rate (cpm or cps) = Gross Count Rate (cpm or cps) – Background Count Rate (cpm or cps)
  - Detector Efficiency = (Counted Activity – Background)/Known Activity
  - dpm = Net Count Rate in cpm / Detector Efficiency
  - 1 microCurie (µCi) = 2.2 X 10^6 dpm
  - dps = Net Count Rate in cps / Detector Efficiency = Bq
  - 1 microCurie (µCi) = 37 kBq
UWO Contamination Limit

• Non-fixed contamination does not exceed 3 Bq/cm² in a designated unsealed nuclear substance room

  • Detector area of a contamination meter for direct monitoring
  • Averaged over an area of 100 cm² for indirect monitoring

• Fixed contamination must be reported to the Radiation Safety Coordinator
Contamination Level  = \frac{S - B}{E \times A \times T \times F} (Bq/cm^2)

- **S** = Sample count rate (cpm or cps)
- **B** = Background count rate (cpm or cps)
- **E** = Detector efficiency (i.e. for 50% efficiency, E = 0.50)
- **A** = Area wiped (100 cm^2) or detector area in cm^2
- **T** = 60 sec/min if count rate in cpm
- **T** = 1 if count rate in cps
- **F** = Collection factor for area wiped (Indirect Monitoring). A value of **F = 0.1** (i.e. 10%) should be used if it is not determined experimentally.
### Examples of Calculated Contamination Limit in Net CPM

<table>
<thead>
<tr>
<th>Contamination Monitoring Method</th>
<th>Contamination Limit (Bq/cm²)</th>
<th>Contamination Limit (Net CPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Monitoring Using Ludlum Model 3 Meter with Detector 44-9 for P-32</td>
<td>3</td>
<td>885</td>
</tr>
<tr>
<td></td>
<td>Indicated on calibration sticker (use 30.93% detector efficiency &amp; 15.9 cm² detector area in the calculation)</td>
<td></td>
</tr>
<tr>
<td>Direct Monitoring Using Ludlum Model 3 Meter with Detector 44-3 for I-125</td>
<td>3</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td>Indicated on calibration sticker (use 16.17% detector efficiency &amp; 4.9 cm² detector area in the calculation)</td>
<td></td>
</tr>
</tbody>
</table>

Contamination Limit (Net CPM) = (Gross or sample count rate in cpm – background or blank in cpm) = (S – B)

Note: background is about 50 cpm
### Examples of Calculated Contamination Limit in Net CPM

<table>
<thead>
<tr>
<th>Contamination Monitoring Method</th>
<th>Contamination Limit (Bq/cm²)</th>
<th>Contamination Limit (Net CPM)</th>
</tr>
</thead>
</table>
| Indirect Monitoring  
(Wipe Test)  
Using A Liquid Scintillation Counter for most radiation emitters  
(e.g. H-3, Ni-63, C-14, S-35, P-33, Ca-45, Cl-36, U-238 etc.) | 3                           | 900                           |
| Indirect Monitoring  
(Wipe Test)  
Using A Well-Crystal NaI Gamma Counter for gamma emitter  
(Cr-51 in this example) | 3                           | 66                            |

(Gross or sample count rate in cpm – background or blank in cpm) = (S – B)  
Note: background is about 50 cpm  
(use 50% detector efficiency, 100 cm² wiped and 10% collection factor as a conservative approach in the calculation)  
(use 3.7% detector efficiency, 100 cm² wiped and 10% collection factor as a conservative approach in the calculation)
Exercise

- How to operate a contamination meter and perform a direct monitoring
Homework

• Review a recent contamination monitoring record of your designated unsealed nuclear substance rooms

• If you have any questions or concerns, contact Radiation Permit Holder or Radiation Safety Coordinator
Standard Operating Procedures

Section 3
Radiation Safety Manual
Permit System

- New Permit/Amendments/Renewal
- Sabbatical/Extended Leave
- Suspension/Cancellation
- Trained/Authorized User
- Max Ordering/Possession
- Inventory/Waste Record
- Records: must be kept for at least three years
Nuclear Substance Room

- Basic, Intermediate or High Level Room Classification for Use of Unsealed Nuclear Substances
- Posting Warning Signs
- Frivolous Posting of Warning Signs
- Radiation warning sign must not be posted where radiation is not present
- Commissioned Room: Authorized by Radiation Safety Coordinator
- Decommissioned Room: Permit Holder or Department Chair’s Responsibility
Security & Access Control

- Designated radiation rooms must be locked at all times when unattended.
- When in storage, nuclear substances or radiation devices are accessible only to persons listed on the radiation permit (e.g. restricted lock box, key control or alarm system).
Purchasing and Receiving

- All purchases/acquisitions/transfers must be approved by Radiation Safety Coordinator
- Nuclear substance shipment is delivered to Room 003, Chemistry Building
- Authorized receiver must be listed on the permit and have been trained within two years
- Inventory/waste record form and bar code sticker are provided to authorized receiver for each shipping vial
• Bar code sticker must be affixed to the shipping vial after completion of wipe test.
Purchasing Procedure

- Create an online purchase requisition through your department
- Ensure permit holder name and permit number on the purchase requisition
- Identify the purchase requisition as “RADIOACTIVE”
- Indicate the catalogue number, chemical compound, sealed or unsealed nuclear substance, name and quantity of the nuclear substance
Purchasing Procedure (cont.)

• Complete the “Ship To” box of purchase requisition as follows:
  • DEPT: Name of Department (e.g. Anatomy)
  • BLDG: Chemistry     DOCK: 11
  • ROOM: 003          POSTAL CODE: N6A 5B7
  • ATTN: Name of Authorized Receiver (e.g. J. Ball)
  • TELEPHONE: UWO phone extension (s) of Authorized Receiver
Types of Radioactive Waste

- Liquid waste: aqueous or organic solvent
- Liquid scintillation vials
- Solid waste: combustible, glass, etc.
- Animal carcasses or tissues
- Biological/radioactive waste
- Stock shipment vials: empty or residual vials
Common Types of Radioactive Waste
Liquid Waste
(Potential of Spill)

- Use plastic container and absorbent pad/dish pan
- Use funnel and do not overfill
- Close cap tight when not in use and during transportation
Determination of Common Radioactive Waste

- Measure total activity of liquid waste for each use or experiment
- Determine total activity of solid waste: total used activity minus total measured activity of liquid waste
Example of Waste Composition

Labeling of protein 100 μCi

0.1 μCi liquid scintillation vials waste

0.1 μCi liquid waste

(about 20ml)

99.8 μCi solid waste
Waste Record & Label

- Record total activity for each type of waste in the inventory & waste form provided by ChemBioStores staff.
- Record permit holder, permit #, nuclear substance, activity, date of activity and type of waste in the radioactive waste labeling form posted on a container or radioactive waste pail.
- Indicate nuclear substance, permit holder, permit #, type of waste in the waste label sticker affixed on a container or radioactive waste pail. Complete all information in the waste label sticker before submitting for disposal.
<table>
<thead>
<tr>
<th>Date Used (m/d/y)</th>
<th>Name of User</th>
<th>Activity Used (eg: 100 uCi)</th>
<th>Activity Remaining</th>
<th>Disposal Method* and Measured Activity for Disposal (eg: L1 = 50 uCi, S1 = 50 uCi)</th>
<th>Date of Disposal (m/d/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/09/2010</td>
<td>Hoa Ly</td>
<td>200 uCi</td>
<td>50 uCi</td>
<td>L1 = 100 uCi, S1 = 100 uCi</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** No radioactive waste shall be disposed to the sewer, regular garbage, transfer or return without consultation with the UWO Radiation Safety Coordinator.
**THE UNIVERSITY OF WESTERN ONTARIO**  
**RADIATION SAFETY PROGRAM**  
**LABELING FORM FOR RADIOACTIVE WASTE CONTAINER/PAIL**

**Permit Holder:** ________________________________  
**Permit #:** __________________________

**Nuclear Substance:** ____________________________  
**Form (check one):**  
☐ solid  
☐ liquid  
☐ LSV

**Instructions:**
1. Attach this labeling form and affix a new yellow radioactive waste label on the side of each container/pail (the old waste label should be removed or covered by the new one) just before discarding any radioactive waste into the container/pail. Note: any radioactive warning signs on an empty container/pail must be removed or covered.
2. Record activity and date of activity on the labeling form every time you discard radioactive waste into the radioactive waste container/pail.
3. When you’re ready to give the radioactive waste container/pail to environmental safety personnel; determine the total activity, complete the affixed yellow radioactive waste label, and keep this labeling form for your own record.

<table>
<thead>
<tr>
<th>Activity (mCi or MBq)</th>
<th>Date of Activity (Month/Day/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Activity:** ____________________________  
**Date of Activity:** ____________________________

**Disposal Date:** ____________________________  
**Name:** ____________________________
RAYONNEMENT — DANGER — RADIATION

Nuclear Substance: ________________
Activity (µCi or MBq): ________________
Date of Activity: ________________
Permit Holder: ________________
Permit Number: ________________

(Check ✓)
- AQUEOUS (Water Soluble)
- COMBUSTIBLE
- GLASS
- HAZARDOUS CHEMICALS
- LIQUID SCINTILLATION VIALS
- OTHER: ________________

List and Quantity (%) of Hazardous Chemicals (if applicable):
_______________________________________________________
_______________________________________________________
Radioactive Waste Disposal Pail

- Each pail contains **Only One nuclear substance and One Type of Waste**
- Use **Only Clear Plastic Bag**
- Perform wipe test and complete the following before submitting for disposal
  - Radioactive Waste Label Sticker
  - Safe Transport of Radioactive Material form
  - Hazardous Waste Disposal form
What Should I Do About My Radioactive Waste?

- Follow the UWO Radiation Safety Training/Manual procedures and submit radioactive waste to the Environmental Safety Personnel
- **DO NOT** discard/discharge radioactive waste to regular garbage or sewer
- Contact Radiation Safety Coordinator if you have any questions or concerns
Documents & Forms

- Nuclear Energy Worker (NEW)
- Dose limits for NEW and Pregnant NEW
- Radiation Risk in Perspective by Health Physics Society
- Risk Assessment by Health Physics Society
- TLD Badge Request
- Receiving Authorization
- Contamination Monitoring Record
- Radioactive Waste Labeling
- Hazardous Waste Disposal
- Safe Transport of Radioactive Material
- Radiation Safety Awareness Record
- Others

These forms are available on the Human Resource web site under documents/forms
http://www.uwo.ca/humanresources/
Biological Effects Of Radiation & Risks
Radiosensitivity

Most radiosensitive

- Bone marrow, lymphoid tissue, reproductive organs, unborn child and rapidly dividing cells

Least radiosensitive

- Muscle, brain, nerve and bone cells

Depending on type of radiation, age at irradiation, absorbed dose, time distribution and dose distribution
Non-Stochastic Effects

(Acute Effects)

- Required extremely high radiation dose to the whole body at one time (1 Gray or higher)
- Un-repairable damaged cell at reproduction
- Enough damaged or dead cells to inhibit tissue function - temporary or permanent
### Non-Stochastic Effects

*(Acute Effects)*

<table>
<thead>
<tr>
<th>Dose (Gray)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>For gamma, X-ray &amp; beta&lt;br&gt;1 Gray (Gy) = 1 Sievert (Sv)</td>
<td></td>
</tr>
<tr>
<td>1 - 10</td>
<td>Nausea, vomiting, diarrhea, bone marrow depression or damage to bone marrow, loss of hair. Medical treatment may prevent death. &lt;br&gt;<strong>LD&lt;sub&gt;50/30&lt;/sub&gt;</strong> is 5 – 7 Gray.</td>
</tr>
<tr>
<td>10 - 20</td>
<td>Severe nausea, vomiting, diarrhea, complete destruction of bone marrow. Death within several weeks is likely even with medical treatment.</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>Central nervous system damage as well as all other organs. Death in a matter of hours to several days.</td>
</tr>
</tbody>
</table>

888000 GBq of Cobalt 60 (gammacell) without shielding has a dose rate of 5.5 Sv/min at 1 m distance.
Stochastic Effects
(Delayed Effects)

• Concern of incorrectly repaired cells - cancer and genetic risks
• Unconfirmed data or no evidence of a lower threshold of the stochastic effects
• Reduce the probability of the stochastic effects by minimizing the risk associated with radiation exposure
• ALARA principle is the best approach today
Radiation Dose Response

Effect (Risk) vs. Dose (Sieverts)

- **Confirmed Data**
- **Unconfirmed Data**

Region of Interest

- **a**
- **b**
- **c**

- **Confirmed Data**
- **Unconfirmed Data**
Radiation Protection & Risk Perspective

- Prevent non-stochastic effects
- Limit the probability of stochastic effects to acceptable levels
- The effects at high doses are well documented
- The difficulty or uncertainties at low doses
- Radiation dose vs. Risk
- Risk vs. Benefits
Dosimetry Services
Personal Dosimetry

• **External Monitoring** (exchanged on semi-annual basis)
  - Whole body TLD badge required for high energy beta (> 1 MeV, e.g. P-32), gamma or neutron
  - Ring dosimeter for handling more than 50 MBq (1.35 mCi) of high energy beta (> 1 MeV, e.g. P-32)

• **Internal Monitoring** (within 5 days)
  - Volatile radioiodine must be used in the fume hood
  - Thyroid screening for use in a 24-hr period of I-125 or I-131 exceeding 2 MBq in an open room (0.054 mCi) or 200 MBq (5.4 mCi) in a fume hood of radioiodine
## External Monitoring

<table>
<thead>
<tr>
<th>Type of Radiation</th>
<th>Nuclear Substance</th>
<th>Whole Body TLD Badge Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha &amp; Low Energy Beta</td>
<td>H-3</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>C-14</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>S-35</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Ca-45</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Fe-55</td>
<td>No</td>
</tr>
<tr>
<td>High Energy Beta, Gamma, &amp; Neutron</td>
<td>Co-60</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Co-57</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Cs-137</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Na-22</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Cr-51</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>P-32</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Uranium</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Sources may be Sealed, Unsealed or from a Radiation Device
Personal Exposure Report
(TLD Badge Report)

- TLD badge coordinator from Health and Safety department will e-mail you that your personal exposure report is ready for review on-line at Mirion Technologies web site: https://www.dosimetry.com/myaccount/register.html OR with your departmental TLD badge coordinator.

- Your personal exposure report is also reviewed by the Radiation Safety Coordinator.

IT IS YOUR RESPONSIBILITY TO REVIEW YOUR PERSONAL EXPOSURE REPORT
### Personal Exposure Report

![Global Dosimetry Solutions Logo](image)

#### Wearers

**Dosage History for GRAY, E (C0014 00000SAF31) in Millisieverts, rounding by One**

<table>
<thead>
<tr>
<th>Wear Date</th>
<th>Badge</th>
<th>Deep</th>
<th>Eye</th>
<th>Shallow</th>
<th>EDE Calc</th>
<th>Deep</th>
<th>Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/01/2018</td>
<td>16WB</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Regulatory Effective Dose Limits

• Nuclear Energy Worker (NEW): 50 mSv in any single year of five years period in total of 100 mSv. The average is 20 mSv/year

• Pregnant NEW: 4 mSv for balance of the pregnancy term

• Non-NEW: 1 mSv/year
UWO Action Levels

- Personal dosimetry for NEW: 2 mSv/year
- Required thyroid monitoring for iodine 125 or iodine 131 users: 1 kBq
- Package containing nuclear substance is damaged/leaking or radiation level of the package is greater than the designated package label
Receiving, Identifying & Opening
Radioactive Packages
Types of Radioactive Shipment

- **Forms:** special form, normal form (unsealed and sealed sources)
- **Common categories:** high level sources (type B), spent fuel (type B), sources above excepted packages limit (type A), excepted packages
- **Radioactive packages are transported** by certified courier, not regular post
Package Types

• **Excepted packages**
  - Typically boxes can stay intact during normal transportation and environmental conditions.
  - Shipping document must contain a phrase: “radioactive material, excepted package, limited quantity of radioactive material, UN 2910”
  - The word “radioactive” that must be seen upon opening the package. No radiation labels required on the outside of the package except UN 2910 label.
Package Types (cont.)

• **Type A packages (shipments > excepted packages limit)**
  - Packages must withstand specific moisture, free drop, stack and penetration tests

• **Type B packages (shipments > type A limit)**
  - Packages must withstand rigorous testing including head-on collision. These packages are heavy metal containers and must be certified by the CNSC.
Package Labels

- **No Label** (excepted package): max 5 μSv/hr
- **White I**: max 5 μSv/hr
- **Yellow II**: max 500 μSv/hr and the transport index does not exceed 1
- **Yellow III**: max 2 mSv/hr and the transport index does not exceed 10
- **Transport Index (TI)** = maximum dose rate at one meter in μSv/hr divided by 10
Vehicle Placard (top left) & Package Labels

- Radioactive
- Radioactive I
- Radioactive II
- Radioactive III
Receiving & Opening Radioactive Packages

- Wear lab coat, disposable gloves and safety glasses while handling the package.
- Monitor the radiation field outside of the package.
- Open the outer package and check for possible damage to the contents. If the contents appear to be damaged, notify RSC immediately.
- If no damage, wipe test the primary container which holds the unsealed nuclear substance (shipping vial).
Receiving & Opening Radioactive Packages

- If contamination is detected, monitor all packaging and other areas coming contact with the package. Contain the contamination, decontaminate and dispose of as radioactive waste.
- Avoid unnecessary direct contact with unshielded container.
- If no contamination, verify all of the details on the packing slip and purchase order with the shipping vial.
- Record all the required information on the UWO inventory form.
Shipping Any Radioactive Packages?

- Contact Radiation Safety Coordinator
Radiological Emergency Response
Emergency Procedure

1. Stop operations immediately, leave fume hood running (if applicable)
2. Inform persons in the area and keep them away from the incident/accident area
3. Confine the incident/accident or spill
   Restrict access to the area. Cover the spill with absorbent material to prevent the spread of contamination
4. Clear and secure the area
   Remove all persons around the area and secure the area. Post warning sign
5. Notify Radiation Safety Coordinator and Permit Holder immediately:

- Major spill (> 100 EQ) for example: 270 μCi or 10 MBq of P-32 is a major spill
- Contamination of personnel or release of volatile material
- If there is a doubt regarding correct procedure
- UWO Radiation Safety Coordinator (weekdays 8:30 am to 4:30 pm) ext. 84746
- UWO-Police (after hours, nights, weekends and holidays) 911 from campus phone
Radiological Spill

• The most important immediately action is to prevent the spread of the spill material
• Stay calm and follow the CNSC spill procedures posted in a designated unsealed nuclear substance room
The Key to Decontamination Procedures

DVD Presentation
Released by
University of Calgary
General Decontamination

- Always treat personal contamination first
- Get assistance from trained personnel if needed
- Wear protective clothing (e.g. lab coat), TLD badge (if required) and use disposable gloves
- Use absorbent material for both dry and wet spill
- Outline the spill area with radioactive tape
- Do not track contamination away from the spill area. Do not let anyone leave the contamination area without being checked for contamination
General Decontamination (cont.)

- Ensure that sufficient materials are available to clean the spill area: gloves, cleaning agents, absorbent pad, etc.
- Use decontamination solution to clean the spill area (e.g. soap & water, commercial radioactive cleaning solution)
- Work from outside towards the centre of spill. Blot and wash the affected area several times
- Discard all cleaning materials as radioactive waste
• Monitor lab coat, hands, clothes, shoes and the entire spill area for any residual contamination

• Record spill details and contamination monitoring results. Adjust inventory and waste records appropriately

• Report to the UWO Radiation Safety Coordinator and Permit Holder
Personal Decontamination

• Ensure medical personnel are aware of contamination area

• Minor cuts: clean the affected area with swabs. If wound is contaminated, wash with large amount of warm water. For face, wash away from mouth, eyes, nose and ears

• After decontamination, monitor for effectiveness and apply first aid
Personal Decontamination (cont.)

- In general, remove contaminated clothing and flush contaminated skin with warm water and mild soap. Repeat wash and rinse several times using soft brush, if necessary. Do not redden the skin.
- In case of chemical contamination, which may react with mild soap, flush skin with warm water only.
- Take a shower for at least 15 minutes for non-localized contamination.
- Contaminated eyes: flush with warm water for at least 15 minutes.
• Notify Permit Holder and Radiation Safety Coordinator immediately following:
  • Lost or stolen of nuclear substance or radiation device
  • Radiation device is damaged or sealed source is separated from radiation device
  • Sealed source fails to return to shielded position inside radiation device
  • Major radioactive spill (> 100 exemption quantity of a nuclear substance), release of volatile material or contamination of personnel
  • An exposure in excess of UWO action levels
Spill Scenario

- Describe how to respond to a selected spill scenario, spill cleaning techniques, contamination control and monitoring
Inspection Exercise

- **Radiation Protection**
Inspection Exercise (cont.)

- Emergencies and Unplanned Events
  - Emergency Procedures and Reports
- Environmental Protection
  - Waste Disposal, Decommissioning
- Training and Qualification
  - Radiation Safety Training Certification, Radiation Safety Awareness, Nuclear Energy Worker Designation
Inspection Exercise (cont.)

• Operational Procedures
  • Use of Equipment and Procedures, Authorized Transfer, Safety Posters, Chairs, Housekeeping, Inventory, List of Authorized Users Posted, Frivolous Posting of Signs, Permit Posted, Record Keeping/Retained

• Security
  • Rooms Locked When Unattended, Sabotage
Inspection Exercise (cont.)

- Organization and Management
  - Worker’s Precautions, Area Classification, Supervision, Change Notified, Radiation Safety Manual, Prohibition of Human Use

- Packaging and Transportation of Dangerous Goods (TDG) Class 7
  - Radioactive Package Received or Shipped, Radiation Safety Training Certificate
Personal Action Plan

- Think “safety first”
- Inform your supervisor/permit holder that you have completed the general radiation safety training, and ask for your name to be added to her/his radiation permit
- Receive specific training on equipment, topic or procedure from your supervisor/permit holder
- Review the radiation safety inspection checklist posted on the UWO Human Resources web site
- Review the radiological emergency response plan
- Work safely to reach your goal