RADIATION SAFETY PROGRAM

CONTENTS

UNIVERSITY OF WATERLOO

1.0 INTRODUCTION

Radioactive materials are used for research at the University of Waterloo. As such, the University has developed this Radiation Safety Program using the concept of ALARA as its guiding principle.

ALARA is a concept that seeks to keep all doses of radiation As Low As Reasonably Achievable based on social and economic factors. No practice involving exposure to ionizing radiation may take place if there is no benefit from that practice. Regardless of the practice, radiation exposures must be kept below federal exposure guidelines.

Refer to Appendix E for more information on ALARA.

2.0 PURPOSE

To provide a reference document that outlines the overall requirements for individuals wishing to work with radioactive materials and devices.

3.0 SCOPE

These guidelines apply to all work conducted under the auspices of the University of Waterloo including work carried out by researchers, instructors, students, workers, and other individuals

4.0 ROLES AND RESPONSIBILITIES

4.1 APPLICANT AUTORITY

At the University of Waterloo, the applicant authority is the Director of Safety. Their role includes the following duties:

- Overseeing the Radiation Safety Program at the University of Waterloo.
- Apply for licenses when materials require it.
- Appoint at least one Radiation Safety Officers (RSO's) to service the University of Waterloo.
- Report the status of radiation safety issues to the Senior Management Safety Committee.
- Ensure unresolved non-compliance issues are resolved in a timely manner.
- Provide resources to researchers and workers to ensure they are working in a compliant manner.

4.2 PERMIT HOLDERS (PRINCIPAL INVESTIGATORS)

The primary responsibility for the safety of staff, students and the public lies with the permit holder in charge of the research or teaching that involves use of the radioactive materials. Permit holders must be familiar with, follow, and ensure that all individuals working within their laboratories comply with procedures outlined in this Radiation Safety Program. In particular, principal investigators and instructors shall:

- Obtain a Radiation-Safety Permit when using a radioactive material above one "Exempt Quantity" (EQ).
- Provide adequate supervision so that all work is in accordance with procedures set out by the UW Radiation Safety Committee and the Canadian Nuclear Safety Commission (CNSC).
- Keep an up to date inventory of all radioactive materials, including storage and disposal records in the laboratory.
- Train all workers, students, interns, and other individuals handling radioactive materials on the risks, how to control them at the University, and in your specific lab.
- Maintain area monitoring and/or wipe test records for inspection by the RSO.
- Ensure all personnel under their supervision wear the appropriate radiation dosimetry equipment and participate in any prescribed bioassay program.
- Immediately contact and notify the RSO should they become aware of reportable activity.

4.3 WORKERS/STUDENTS

Workers/students handling potentially radioactive materials are required to:

- Undergo any training as required by their direct supervisor and the University.
- Follow procedures developed for a specific laboratory or project and the overall University and CNSC processes for the handling of radioactive materials.
- Wear personal protective equipment as prescribed.
- Immediately inform the Principal Investigator (PI) if:
    - You suffer an exposure or believe you have been exposed to a radioactive agent.
    - There is a spill of radioactive material.
- Immediately inform the Principal Investigator if you are aware of a "Reportable Activity" occurring.

4.4 RADIATION SAFETY OFFICER (RSO)

The Radiation Safety Officer is required to have both theoretical and practical experience. A Curriculum Vitae is submitted to the CNSC for anyone designated as a Radiation Safety Officer at the University of Waterloo.

4.4.1 DUTIES OF THE RADIATION SAFETY OFFICER (RSO) WITH RESPECT TO THE UNIVERSITY

- Act as the agent of the institution in respect to licensing matters.

- Be available to the licensee effectively on a full-time basis.
- Establish, implement, and maintain a safety control and assessment program in conjunction with the UW Radiation Safety Committee.
- On a semester basis, review survey programs for radiation and contamination levels in all areas where radioactive materials are used, stored or disposed of.
- Implement a personnel-monitoring program including bioassay, if applicable.
- Calibrate and service radiation safety instruments as required.
- Conduct a quarterly review of occupational radiation exposures and recommend ways of reducing exposures in the interest of ALARA.
- Supervise decontamination procedures.
- Provide waste disposal procedures in accordance with conditions of the radioisotope license.
- Ensure leak testing of sealed sources.
- Control the purchasing, use and disposal of radioactive materials through the issuance of internal permits.
- Ensure appropriate radiation protection training is provided on a regular basis as part of an ongoing "radiation protection awareness program" for all users and those who are exposed to radioactive materials.
- Maintain required records.
- Amend each internal permit when necessitated by changes to facilities, equipment, policies, isotopes, procedures or personnel.
- Co-ordinate the development of plans used in the case of an emergency involving radioactive materials.
- Investigate all overexposure, accidents, and losses of radioactive materials and report to the CNSC.
- Report any “Reportable Activity” in a timely fashion to the CNSC.

4.4.2 DUTIES OF THE RSO WITH RESPECT TO THE RADIATION SAFETY COMMITTEE

- Function as the link between the University Radiation Safety Committee and radioisotope users within the institution.
- Prepare or review in consultation with the UWaterloo Radiation Safety Committee a comprehensive Radiation Safety Program.
- Prepare in consultation with the Radiation Safety Committee, an Annual Report to the CNSC or as required
- Provide direction pertaining to:
    - Facility and equipment design

- Work practices and procedures
- Waste storage and disposal management
- Evaluation, issuance and enforcement of internal permits
- Disciplinary action necessitated by noncompliance
- Radiation safety training

4.5 RADIATION SAFETY COMMITTEE

The purpose of this committee is to provide oversight regarding activities involving radioactive materials. The committee will focus on the following:

- Review planned laboratory activities to ensure the completion of an appropriate hazard identification, and a risk evaluation of activities.
- Assess requirements and recommend revisions for laboratory users training and laboratory safety procedures.
- Review reports related to laboratory safety services, activities, incidents, and interventions in laboratory areas and recommend corrective actions.
- Reports as required to the Vice-President of Research at the University of Waterloo.

5.0 WORKER DESIGNATION, QUALIFICATIONS AND EXPERIENCE

Only persons expected to receive a dose more than 1.0 mSv per year whole body will be designated as Nuclear Energy Workers (NEW). Workers designated as a Nuclear Energy Worker (NEW) must complete a Notification of Nuclear Energy Worker Status (PDF).

Workers performing general laboratory tasks as part of University research would not expect to receive a whole body dose more than 1.0 mSv per year and therefore, are not designated as Nuclear Energy Workers.

6.0 TRAINING

Researchers, workers, and students handling radioactive materials and isotopes are required to complete all the elements of the University's Radiation Safety Training Program.

6.1 REQUIRED TRAINING

Radiation safety training has the following three elements:

- Online radiation safety training which provides a basic background on the dangers of radiation, how one can become exposed, and the basic principles of limiting exposure.
- The completion of basic practical radiation safety training.
- The completion of laboratory specific practical radiation safety training.

Any University of Waterloo worker or student with a valid UWaterloo user ID and password can access the online training. The material covered in this training module provides the worker/student with general radiation safety procedures.

Please open the following link to access the online training: https://uwaterloo.ca/safety-office/training/working-with-radiation.

Students, workers or researchers receive laboratory and project specific training in two separate parts. The Safety Office provides basic practical radiation safety training which reinforces the information provided in the online training module. It also outlines best practices for the handling and disposal of radioactive materials.

The Principal Investigator (PI) or a competent designate provides the laboratory specific practical radiation safety training. It should encompass the specific procedures used in the laboratory for the handling, use, and disposal of radioactive material. It should also include training on emergency procedures, the use of the emergency equipment, and reporting protocols used in the laboratory.

It is the responsibility of the PI to track the training they provide to their workers and students.

Individuals working with radiation shall be re-trained every 3 years.

6.2 RECOMMENDED TRAINING

The Canadian Nuclear Safety Commission (CNSC) has numerous online resources that help individuals understand how to work safely with radioactive materials and that outline the best practices expected when working with radioactive materials. If you are working with radioactive materials, please consider viewing the following free online resources: http://nuclearsafety.gc.ca/cnsconline/fl/index-eng.cfm.

7.0 PERMITS

A permit system maintains the control of radioactive materials at the University of Waterloo. The UW Radiation Safety Committee issues radiation Permits to all principal investigators/instructors handling radioisotopes. However, only those PI's who use radioactive materials above Exempt Quantities (EQ) are required to complete the permit application. Those using materials below the EQ are issued permits to assist with the tracking of sources.

7.1 APPLYING FOR A PERMIT

To obtain a permit, follow the process outlined in Figure 1.

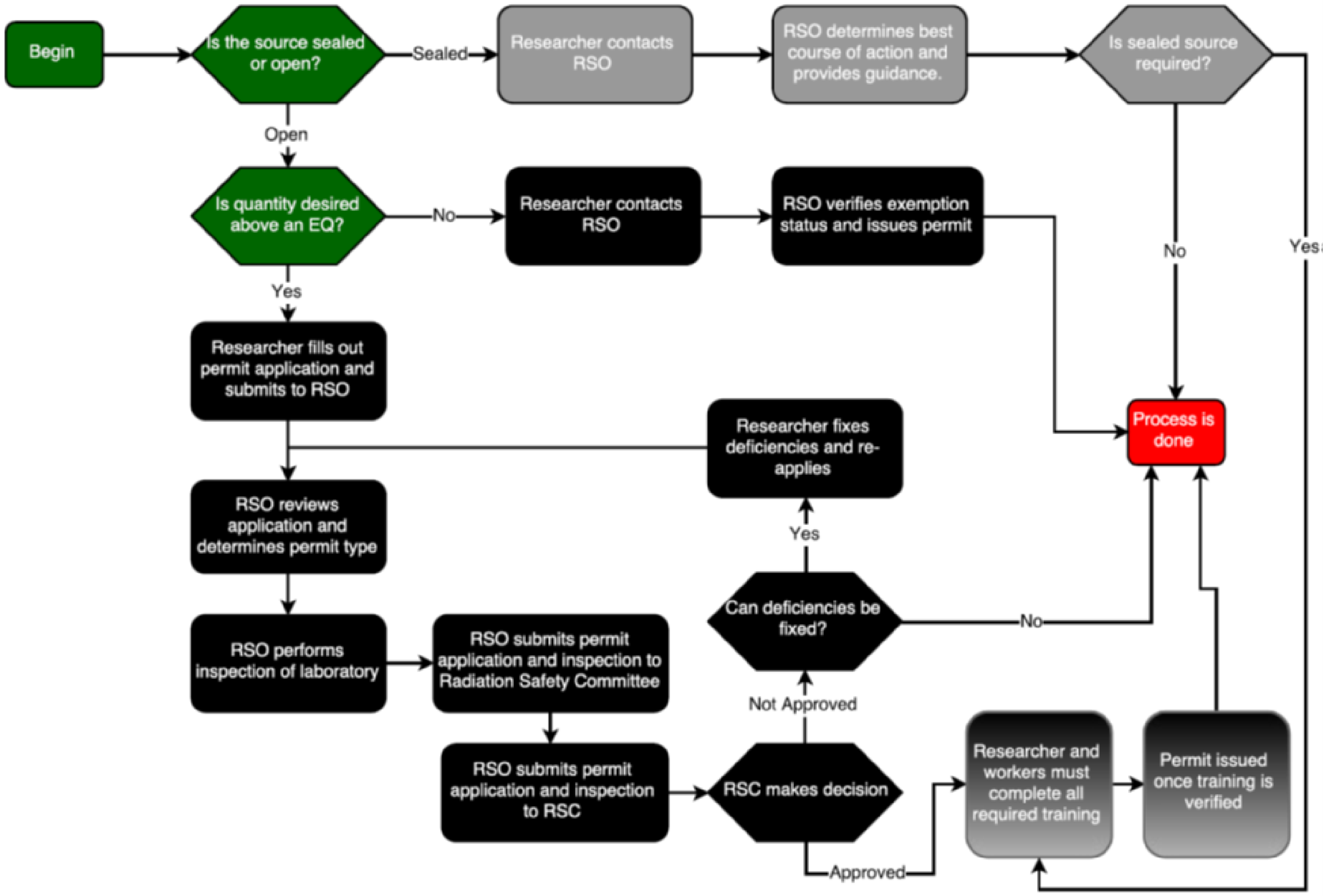


Figure 1: Radiation Permitting Process

- Green boxes indicate the start of a process.
- Black boxes correspond to open sources.
- Grey boxes correspond to sealed sources.
- Red boxes denote the end of the process.

Permits will not be issued until all training for all users has been completed and verified. The permit certifies the laboratory for work with the specific radioisotopes and amounts indicated. Working outside these limits is prohibited unless you amend your permit.

7.2 TYPES OF PERMITS

The CNSC classification for laboratories using open sources consists of three designations: Basic, Intermediate, and High. The designations are based on the Annual Limit on Intake or (ALI). An Annual Limit on Intake is defined by the CNSC as the activity, in becquerel, of a radionuclide that will deliver an effective dose of 20 mSv during the 50-year period after the radionuclide is taken into the body of a person 18 years old or older or during the period beginning at intake and ending at age 70 after it is taken into the body of a person less than 18 years old. Table 1 lists the criteria for classification.

Table 1: CNSC classifications for laboratories using open source radioactive materials

Room Classification	Description
Basic	The quantity of unsealed nuclear substance used at a single time does not exceed 5 times its corresponding annual limit on intake (ALI).
Intermediate	The quantity of unsealed nuclear substance used at a single time does not exceed 50 times its corresponding ALI.
High	The quantity of unsealed nuclear substance used at a single time does not exceed 500 times its corresponding ALI.

For sealed sources, classifications are different. The source itself is classified based on the activity and the potential hazard it could cause. Criteria outlined by the CNSC for determining the categories include:

- Radiological risk associated with the source
- Nature of the work (or application for which the source is used)
- Mobility of the source
- Experience from reported accidents
- Typical versus unique activities within an application

For a more detailed description, with examples, go to: http://nuclearsafety.gc.ca/eng/nuclear-substances/licensing-nuclear-substances-and-radiation-devices/sealed-source-tracking.cfm

7.3 AMENDING OR DECOMMISSIONING A PERMIT

Follow the steps below to amend a permit. To decommission a permit, contact the RSO.

1. Make a list of the radioisotopes you wish to add to or remove from the permit.
2. If adding isotopes, identify what activity you would like to perform with each of the additional isotopes.
3. Contact the RSO and provide the isotopes and the activities to them.

8.0 LICENSED LOCATIONS

Radioactive materials can only be used or handled in permitted locations. Before use, notify all personnel expected to be in the area about the use of the material, and take precautions to ensure that the maximum allowable working field of 2.5 uSv/hr in any direction from the source is not exceeded.

8.1 WORKING PRACTICES

Before beginning work with radioactive materials, consider the following:

Has the appropriate signage and labelling been affixed to laboratories, specific work areas (sinks and fume hoods), and the radioactive material itself?

- Label all radioactive materials with the isotope name, activity, and the user name.
- Laboratories containing radioisotopes need the following labels:
  - Cupboards containing radioisotopes should have a "CAUTION RADIOACTIVE MATERIALS" sign.
  - Refrigerators require a radiation sign.
  - Fume hoods used with radioactive materials require a radiation warning sign.
  - All unsealed radioactive sources need to be locked away in a lockbox when not in use. The lockbox requires a radioactive material sticker.
  - Do not conduct work near or around sinks in order to prevent environmental contamination and be sure to post reminders in the area.

Have you properly assessed the workspace to ensure you can maintain a clean contamination free environment?

- **Work Surfaces** – If the work being conducted cannot be performed in a fume hood, the PI should consult with the RSO for advice. Some considerations for work surfaces in general include:
  - Work surfaces require covering with a plastic backed absorbent to make cleaning up spills and drops easier. Some examples include Benchkote or incontinence pads.
  - Another option is to use secondary containment in the form of plastic trays lined with paper. If using a Benchkote, remove it after the work period, and apply a fresh piece afterwards.
- **Fume hoods** - If there is a possibility of a radioactive material becoming airborne, use a fume hood for the work. This will minimize risk to workers and by-standards should a radioactive material become airborne. The fume hood face velocity should have been verified within the year and have a verification sticker of sash height and flow rate. If the verification sticker is past one year, call plant operations and have the hood flow verified before starting work. If the fume hood does not have a flow indicator, tape a piece of tissue paper on the bottom of the sash to verify flow. Complete a full set of wipe tests after the work is complete.
- **Sinks** – Minimize use of sinks in work with radioactive materials as the release of radioactive materials down the drain is prohibited.
- **Freezers and Refrigerators** - If materials are stored in the refrigerator, ensure they have a label with the user's name, the date, isotope and activity. If storing materials in freezers, consider aliquoting the material into smaller

more usable volumes that are shielded and stored. This helps reduce multiple freeze-thaw cycles which may degrade the compound. De-thaw, scrape clean and wipe test refrigerators and freezers routinely.

8.2 EXPOSURE CONTROLS

Each type of radiation has different properties with different potentials for harm. The table below lists key properties of each.

Table 2: Types of radiation and their properties

Type of Radiation	Description	Ionization	Comments
Alpha particles	• Heavy particle that resembles a Helium atom • Double positive charge • Travels only 7 cm in air • Only emitted by large atoms (atomic # > 82)	Direct or indirect	These have low penetrating power and are not considered an external radiation hazard. If ingested or taken into the body they can cause significant internal damage.
Beta particles	• Small particle with little mass • Negative charge • Travels 200 cm in air • Negative beta decay (neutron -> proton) emits electrons (more common) • Positive beta decay (proton -> neutron) emits positrons (rare)	Direct or indirect	Low to moderate energy beta particles will penetrate about 0.2 cm into skin but no farther. High-energy particles can penetrate further, but are rare. When beta particles pass through matter they can form x-rays (called bremsstrahlung), therefore shielding considerations are more complex for beta radiation.
Neutrons	• Heavy particle • Manmade in nuclear fission and fusion reactions • No charge	Direct	High-speed nuclear particles that have an exceptional ability to penetrate other materials. Neutrons are the only type of radiation that can make other objects radioactive. This is called neutron activation.
Gamma-rays	• Made up of photons • Shorter wavelength then x-rays • Gamma-rays come from nuclei of a radioactive atom after an alpha or beta decay.	Indirect	These rays can theoretically travel forever, but as they pass through matter, they lose their intensity.
X-rays	• Made up of photons • Formed when high speed electrons are slowed down or change direction because of atoms in the target material	Indirect	These rays can theoretically travel forever, but as they pass through matter they lose their intensity.

8.3 FIVE PRINCIPLES OF EXPOSURE CONTROL

Follow these five basic principles to minimize exposure to radioactive materials:

1. **Time*:*** The dose of an individual is directly proportional to the time spent in the radiation field. The half-life of a radionuclide is exponential with time:

Table 3: Equation key

Variable	Definition	Units
A_t	Activity at time t	Bq
A_0	Initial Activity (t=0)	Bq
$t_{(1/2)}$	Time to decay to ½ of the starting amount	Time
λ	Decay constant	Time(-1)

Activity equation	Half-life equation
$A_t = A_0 e^{-\lambda}$	$t_{\frac{1}{2}} = \frac{\ln(2)}{\lambda}$

From the equations above, the following general relationships hold true:

- Waiting one half-life will decrease the activity by a factor of 2.
- Waiting seven (7) half-lives will drop the activity to 1% of the original activity.
- Waiting ten (10) half-lives will drop the activity to 0.1% of the original activity.

Therefore, waiting a few half-lives prior to commencing work with short-lived sources (on the order of minutes or hours), is an effective and practical way of reducing potential exposure.

Another way to reduce exposure is by performing dry runs of any new procedure. Dry runs will identify any missing equipment, improper layout, and potential spill problems. It will also allow one to become familiar and competent with the procedure, which allows for the identification of potential errors and problems overlooked while creating the processes; and, it improves the efficiency of operators.

Overall, this can reduce worker exposure by minimizing time spent working with the source.

2. **Distance*:*** When a gamma ray or x-ray originate from a point source, their intensity is inversely proportional to the square of the distance (see Figure 2 below).

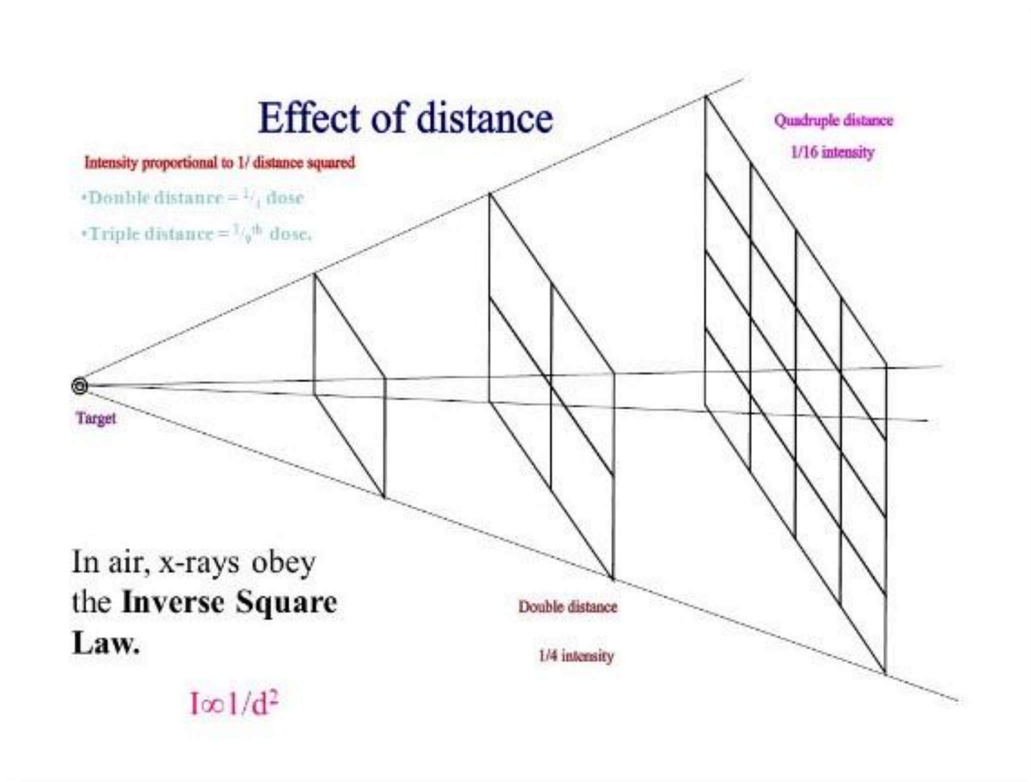


Figure 2: Illustration of how the intensity of radiation will vary with distance

The mathematical relationship of Figure 2 is:

$$\frac{D_1}{D_2} = \frac{(d_2)^2}{(d_1)^2}$$

Table 4: Equation key

Variable	Definition	Units
D_1	Radiation dose rate at d1	μSv/hr
D_2	Radiation dose rate at d_2	μSv/hr
d_1	Distance at point 1	Doesn't matter as long as units are same as d_2
d_2	Decay constant	Doesn't matter as long as units are same as d_1

Example: Consider a source in which the dose rate at 10 cm is 12 uSv/h. If a worker were to move the source from 10 cm to 20 cm, what would the new dose rate be?

Summary of Variables:

I_1	= 12 uSv/hr	Given
I_2	$= I_1 (D_1)^2/(D_2)^2$	Rearrange formula
D_1	= 10 cm	Given
D_2	= 20 cm	Given

Therefore, in this example, the intensity at distance of 20 cm will equal:

= 12 uSv/hr * [10(~~cm~~)^2/20(~~cm~~)^2]

= 3 uSv/hr

In this example, doubling the distance will decrease the intensity by a factor of 4. In practical terms, tools such as forceps and tongs can help increase the personal distance to a source, thus reducing exposure. This relationship only works for a point source, and only for x-rays and gamma rays.

3. **Shielding**: Refers to the act of surrounding a source with a material or object that can completely stop the spread of radiation. Shielding is employed when other suitable protection measures (like increasing distance, or time) are not practicable. The material used to shield the object is dependent the type of radiation emitted and the energy of the emitter.

   The figure below illustrates how radiation types penetrate various materials.

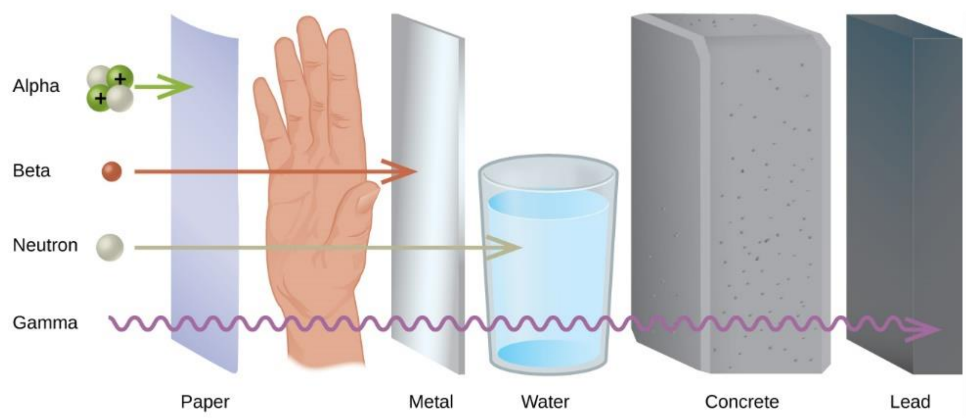


Figure 3: Comparing penetration potential between various radiation types and materials.

As discussed previously, alpha particles are not considered an external radiation hazard and therefore shielding is not required for alpha particle emitters.

Beta emitters require shielding, but if shielded improperly, they may create x-rays called bremsstrahlung. To avoid or minimize the generation of bremsstrahlung, shielding materials must be composed of materials with a low atomic number. Examples of these items include plexiglass, Lucite, or even glass.

Gamma emitters require thick, dense shielding. Materials composed of lead tend to be best. However, in many cases, atoms that emit alpha or beta radiation will also emit gamma radiation, thus both emissions require consideration. Shielding these materials requires layers, with the first layer composed of a beta shield (glass/plexiglass), and the second layer composed of a gamma shield (lead).

The ability of a material to act as a shield for x-rays and gamma rays is defined using two terms:

- The half-value layer (HVL) – thickness of a material to reduce the radiation field to half of its initial value.
- The tenth value layer (TVL) - thickness of a material required to reduce the radiation field to one-tenth of its initial value.

  This helps calculate theoretical radiation fields after shielding. The table below provides guidance on the use of shielding materials on different types of radionuclides.

Table 3: Summary of radionuclides, maximum energies & minimum shielding requirements

Source	Radiation Type @ Max E	Type of Shielding
Tritium (H-3)	Beta @ 18 keV	Glass vial is good enough
Carbon – 14 Sulphur – 35 Calcium – 45	Beta @ 156 keV Beta @ 167 keV Beta @ 252 keV	• For kilobequerel – glass container is good enough • For tens of megabecquerel – 3 mm Plexiglass, lucite, or glass
Phosphorus – 32	Beta @ 1.71 MeV	1.2 cm thick Plexiglass
Phosphorus – 33	Beta @ 0.286 MeV	• For kilobequerel – glass container is good enough • For tens of megabecquerel – 3 mm plexiglass, lucite, or glass
Iodine - 125	Gamma @ 35 KeV	• 1 mm thick lead sheets; or • Glass or clear plastic containing equivalent concentrations of lead
Sodium – 22	Beta @ 1.27 MeV Gamma @ 545.5 keV	▪ 10 cm lead (2 layers of 2” lead bricks)
Chromium – 51	Gamma @ 320 keV	▪ 2 cm lead (3/4”)
Cobalt - 57	Beta @ 1.18 MeV Gamma @ 0.662 MeV	▪ 1.7 mm lead (1/8”)
Rubidium – 86	Beta @ 1.774 MeV Gamma @ 1.077 MeV	▪ 10 cm lead (2 layers of 2” bricks)
Cesium - 137	Beta @ 511 keV Gamma @ 662 KeV	▪ 10 cm lead (2 layers of 2” bricks)

4. **Contamination Control**: Identifying when a work area or piece of equipment becomes contaminated with radioactive material is an integral part of any Radiation Safety Program. Accidental contamination can happen at any time. The basic principles of contamination control are:
   - Designate specific areas and equipment within the lab to use with radioactive materials.
   - The designated bench/work area should be in low traffic areas.
   - If a fume hood is required for work, select bench areas adjacent to it.
   - Keep the area as small as possible with sufficient room to perform the needed tasks.
   - Use Benchkote or another appropriate absorbent for the area – and it should be changed frequently (or at the end of the working period).
   - If possible, designate one sink in the lab for radioactive work.
   - Use warning tape to identify these areas.

- Use warning tape to label equipment (waterbaths, centrifuges, incubators, etc.) used in conjunction with radioactive materials.

  There are two ways to detect contamination:

  1. Direct contamination reading
     - Direct reading involves the use of portable detectors or survey meters to detect high-energy beta emitters, x-rays, and gamma radiation. To use these meters, the user would position it 2 cm above the surface to be measured and then move the meter slowly overtop the area in a grid-like manner.
     - Low-energy beta radiation cannot penetrate the detector window and therefore cannot be detected using portable or survey meters.
  2. Wipe testing
     - Wipe testing involves moistening a disc of filter paper with ethanol, then rubbing it over a 10 x 10 cm area (100 cm2). Finally, count it in a liquid scintillation counter (or gamma-well counter).
     - If a result indicates that contamination is greater than 100 counts per minute, decontamination and successive wipe testing are required until levels are below the 100 counts per minute value.

  Appendix 3 contains general equipment decontamination procedures.

5. **Use of Personal Protective Equipment**: Individuals who work with radioactive materials must also take precautions to protect themselves from exposure. This includes wearing the appropriate personal protective equipment like gloves, laboratory coats, shoes, pants, and glasses, goggles or face shields.
   - **Gloves:** Gloves are mandatory when working with radionuclides. They should be checked prior to and frequently during use for small holes or punctures. Disposable gloves are prone to fail and therefore best practice is to double glove. This provides added protection but also ensures that work does not need to be immediately interrupted should the outer pair become damaged. Gloves are prohibited from being worn outside the lab.
   - **Laboratory Coats:** Help ensure the users personal clothing is protected from spills and splashes. Coats should have cuffs rolled down and tucked within gloves. Gloves are prohibited from being worn outside the lab.
   - **Eye Protection:** Projects involving work that agitates, mixes, sonicates, or spins liquid materials must be done while wearing eye protection. At a minimum, this means safety glasses with side shields are required. If splash potential is high, face shields should be used.
   - **Clothing:** Follow these guidelines when working with radionuclides:

- Remove jewellery, especially rings. If jewelry becomes contaminated, it may not be possible to adequately decontaminate it meaning it may not be able to be worn again.
- Pants should be worn to provide splash protection on the lower limbs. Do not tuck pants into boots, as a spill will travel down the pant and into the boot
- Wear closed toe shoes

6. **Other considerations:** It is always best to minimize the potential for exposure by utilizing the principles of increasing the distance, time, or shielding the source. In some cases, using these techniques may not be possible. In these situations, purchase and wear lead aprons.

8.4 EMERGENCIES

Personnel using radioactive materials must be knowledgeable of all the policies, procedures, and processes that are to be followed should an incident or accident occur. Any situation, especially involving personal contamination, MUST be immediately reported to one of the RSO's on campus. During regular work hours, (8:30am to 4:30pm) RSO contact information is as follows:

Table 4: RSO contact information

Primary RSO:	Secondary RSO:
Greg Friday Phone: 35755 Email: gfriday@uwaterloo.ca	Dhananjai Borwankar Phone: 36268 Email: dsborwan@uwaterloo.ca

If an incident occurs after hours, contact campus police at extension 22222 and they will contact whichever RSO is available. No work shall resume after an incident until one of the RSO's has indicated the site is permitted to continue work.

The three most likely emergencies when working with radioactive materials at the University of Waterloo are spills, a leaking sealed source, and contamination of personnel.

8.5 SPILLS

Preparing for spills will result in a much less severe outcome. Being prepared means knowing:

- The location of spill response equipment in the work area.
- How to use the equipment.
- How to communicate the spill.

A radiation spills kit should include:

- Disposable latex gloves and foot covers
- Plastic bags for waste disposal
- Radiation tape and cleaning rags
- Absorbent materials (e.g, paper towel and absorbent pads)
- Organic solvent
- Wax pencil
- Warning signs and/or caution tape
- Contamination testing materials (e.g., monitoring devices and filter paper)
- Decontamination detergent (recommendations: Sparkleen, Fantastik, or Alconox)
- Gritty cleanser
- Waste labels
- Tongs and/or forceps
- Protective eyewear (safety glasses with side shields or a face shield)

Appendix 1 contains specific spill cleaning steps.

8.6 SEALED SOURCE LEAKS

The primary hazard from a broken or leaking sealed source is external gamma radiation. To reduce the risk of exposure, follow this procedure:

1. Evacuate the area and post signs.
2. Monitor and cordon off the "Hot Area".
3. Monitor all personnel.
4. Notify your Supervisor an RSO, and commence personnel decontamination procedures.
5. Use a remote handling device such as tongs and forceps to put the source into a shielded container.
6. Use spill clean-up procedures outlined in Appendix 1 to decontaminate the area.

8.7 PERSONNEL CONTAMINATION

Personnel contamination is either external or internal. External contamination is usually the result of a splash or spill on the individual. Internal contamination occurs when a source has been accidentally ingested or injected into an individual. Appendix 2 outlines the external decontamination procedures.

8.8 LOSSES OR THEFTS OF RADIOACTIVE MATERIALS

Losses or thefts of radioactive materials are treated very seriously by the Canadian Nuclear Safety Commission (CNSC) and requires immediate reporting to them. As soon as loss of theft has been discovered, it is imperative that one of the RSO's are notified so they can contact the CNSC to file a report and begin the investigation.

9.0 APPENDIX A: SPILL PROCEDURES

General Precautions

1. Inform persons in the area that a spill has occurred. Keep them away from the contaminated area.
2. Cover the spill with absorbent material to prevent the spread of contamination.

Minor spills (less than 1 exempt quantities and non-volatile)

1. **Proceed if you feel comfortable in cleaning up the spill, if not, contact the RSO for help.**
2. Inform occupants of the room as to the nature and location of the spill.
3. Limit movement near the spill.
4. Put on 2 pairs of disposable gloves, lab coat and respiratory protection if the substance is volatile, or aerosol generation is suspected.
5. Mark the location of the spill with a wax pencil and begin approved decontamination procedures as soon as possible.
6. Place absorbent paper on spill if wet. DO NOT rub area – as moving towels around may spread contamination. Frequently dispose of used towels.
7. If spill is a powder, wet with water/organic solvent and place absorbent paper on wetted material.
8. To avoid spreading the contamination, work from the outside of the spill towards the center.
9. Do not track contaminants away from the spillage area.
10. Place contaminated absorbent paper in sealable container with appropriate shielding and label.
11. Following decontamination, check the area for any residual contamination. Repeat decontamination, if necessary, until contamination monitoring results meet the radioisotope license criteria.
12. If the spill cannot be cleaned-up, call the Radiation Safety Officer at ext. 35755 or contact UW Police ext. 22222.
13. Report the spill and cleanup to the supervisor and the Radiation Safety Officer at ext. 35755 within 24 hours.
14. Record spill details and the results of contamination monitoring. Adjust inventory records.

Major spills (more than 1 exempt quantities or volatile materials)

1. Clear the room. Persons not involved in the spill cleanup should be prevented entry.

2. Call the Radiation Safety Officer at ext.35755 (do not leave a voice mail message). If not in, contact UW Police at ext. 22222.
3. Limit the movement of all personnel who may be contaminated until they are monitored.
4. Leave the fume hood running to minimize the release of volatile radioactive materials into adjacent rooms and hallways.
5. Close off and secure the spill area to prevent entry. Post warning signs that indicate entry is prohibited.
6. If an individual has become contaminated, follow the decontamination procedures found below in Appendix 2.
7. Record names of all individuals involved or witnessing the spill. Note details of personal contamination.
8. Submit an incident report to the Radiation Safety Officer within 24 hours of the incident.

Table 4: List of exemption quantities

Radionuclide	Exemption quantity (mCi)	Exemption quantity (MBq)
C-14	0.27	10
H-3	27	1000
I-125	0.027	1
P-32	0.0027	0.1
P-33	2.7	100
S-35	2.7	

10.0 APPENDIX B: DECONTAMINATION PROCEDURES

Table 5: Decontamination procedures

External (Skin)	External (Orifices)	Contaminated Wounds	Contaminated Clothing
▪ Use mild soap and warm water. DO NOT use hot or cold water. Hot water opens pores and increases blood flow (increased absorption). Cold water may not be effective. ▪ Rub for 2 to 3 minutes. RUB DO NOT SCRUB – scrubbing may cause abrasions in skin (potentially causing internal contamination). Work from center of body outward ▪ If hands are contaminated, pay special attention to finger nails. ▪ Monitor body. Repeat washing if contamination is still present.	▪ Eyes – Rinse at an eyewash station for 15 minutes. ▪ Mouth – Rinse mouth with water but DO NOT SWALLOW. ▪ Nose – Blow nose and keep tissue for further monitoring. The nose filters can filter much of the particulate and aerosols that are inhaled. ▪ Ear – Tilt head and allow liquid to drain out on a tissue. Keep for monitoring.	▪ Remove gloves and turn inside out. Save item that cause the wound. Gloves and item will be used for contamination monitoring. ▪ Allow wound to bleed. Flush gently with water. ▪ Bandage and cover wound.	▪ Put on a clean pair of gloves. Carefully remove all contaminated clothing and turn inside out as you remove. ▪ This will help to prevent further spread of contamination. ▪ After removal, monitor all exposed skin areas. ▪ Bag contaminated clothing and provide to RSO for further action.

In all cases, contact the Radiation Safety Officer as soon as possible. Extension 36268, or 35755. Do not leave a message. If there is no answer contact campus police at extension 22222.

11.0 APPENDIX C: REPORTABLE ACTIVITIES

General Precautions and Materials

1. Always wear PPE when attempting to perform decontamination operations. Minimum requirements are using double gloves, labcoat, and safety glasses with side shields or goggles.
2. Use disposable materials like paper towels or absorbent pads.
3. Decontamination Products include:
    1. 2 table spoons of Alconox or Sparkleen can be dissolved in water to make a paste.
    2. Fantastik can also be affective.
4. Methods recommended are washing, scrubbing, and abrasion. Always progress from the least aggressive to the most aggressive. Note: scrubbing and abrasion are not recommended for personnel exposure. Any grinding, sanding, scraping or chipping methods shall not be used as they may cause contamination to become airborne. If you think these may be your only options, contact and consult with the RSO before beginning.

Procedures

1. Complex items (lots of crevices and cracks) should be disassembled prior to decontamination – do not disassemble the item if item integrity is lost (contact RSO for guidance).
2. Scan surface of item to determine area of highest contamination.
3. Start at the edge and work your way inwards OR start at the area with the highest contamination readings. Change towels frequently so contamination is not spread along surface of item (i.e., make only one to two passes before discarding towels).
4. Dispose of towels in pail lined with plastic bag.
5. Frequently monitor surfaces after conducting wipes.
6. Conduct swipe tests to ensure there is no removable contamination.
7. Items that cannot be decontaminated must be labelled as a radioactive item, and treated as such.

Once procedures are complete, remove gloves, wash hands and monitor yourself for contamination. If you or your clothing are contaminated, use the personal decontamination instructions in Appendix 2.

12.0 APPENDIX D: RADIATION CONTAMINATION SURVEY FORMS

Fixed Contamination using Geiger Muller Detector

Building_________ Room______ Geiger Muller Detector_____________________

Isotope _________ Detector Efficiency _________ Detector Area __________cm^2

Multiplication Factor (MF) ___________ 1/ (Detector Efficiency)(60)(Detector Area)

Calculation for contamination CPM - CPM(blank) X MF = Bg/cm2

Name			**Name**			**Name**		
Date			**Date**			**Date**		
Area	**CPM**	**Bq/cm²**	**Area**	**CPM**	**Bq/cm²**	**Area**	**CPM**	**Bq/cm²**
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
10			10			10		
11			11			11		
12			12			12		
Background			Background			Background		

Maximum limit of Contamination (Class C radionuclides) is 3.0 Bq/cm^2 averaged over an area of 100 cm^2. Contamination exceeding this level must be reported to the RSO.

Removable Contamination using Crystal Scintillation Detection for ^{125}Iodine

Building_______Room______ Crystal Scintillation Counter____________

Wipe Efficiency: 0.01, **Detector Efficiency:** 0.5, **Wipe Area:** 100 cm², **Multiplication Factor:** 0.0033

Calculation for contamination $(CPM_{sample} - CPM_{blank}) X 0.0033 = Bg/cm^2$

Name			**Name**			**Name**		
Date			**Date**			**Date**		
Area	**CPM**	**Bq/cm²**	**Area**	**CPM**	**Bq/cm²**	**Area**	**CPM**	**Bq/cm²**
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
10			10			10		
11			11			11		
12			12			12		
Background			Background			Background		

Maximum limit of Contamination is 3.0 Bq/cm² averaged over an area of 100 cm². Contamination levels exceeding this level must be reported to the RSO.

Removable Contamination using Liquid Scintillation Detection for Beta Emitters (^{3}H, ^{14}C, ^{32}P, ^{35}S)

Building _____ Room ____ Liquid Scintillation Counter____________

Wipe Efficiency 0.01, **Detector Efficiency** 0.5, **Wipe Area** 100 cm^2

Multiplication Factor 0.0033

Calculation for contamination (CPM $_{sample}$ – CPM $_{blank}$) X 0.0033 = Bq/cm2

Name			**Name**			**Name**		
Date			**Date**			**Date**		
Area	**CPM**	**Bq/cm²**	**Area**	**CPM**	**Bq/cm²**	**Area**	**CPM**	**Bq/cm²**
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
10			10			10		
11			11			11		
12			12			12		
Background			Background			Background		

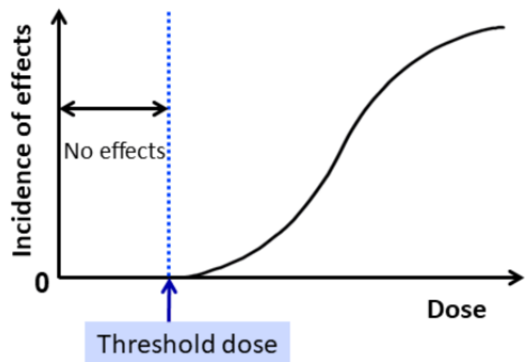
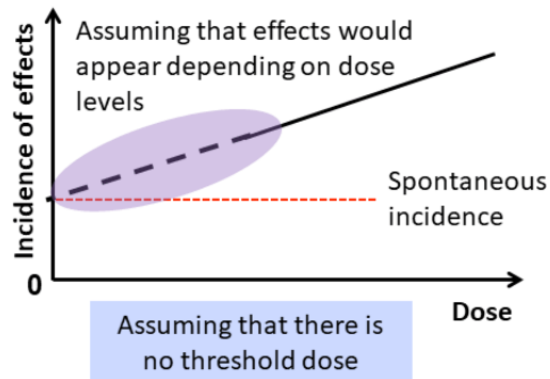
Maximum limit of Contamination (Class C radionuclides) is 3.0 Bq/cm^2 averaged over an area of 100 cm^2. Contamination exceeding this level must be reported to the RSO.

12.0 APPENDIX E: ALARA AND THE EFFECTS OF RADIATION

In general, radiation can affect people in one of two ways:

- Deterministic effects
- Stochastic effects

Table 5: Differences between Deterministic and Stochastic effects

Deterministic effects are those effects that appear after meeting some threshold value of exposure. Once below that threshold of exposure, no effect is observed. In this case, the severity of the effect is dependent upon dose. Generally speaking, legislative limits are far lower than threshold doses of radiation.  	Stochastic effects are ones that do not have a threshold value, meaning that the probability that effect will appear increases as dose increases, but the severity of the effect is independent of dose. 
E.g., Hair loss, cataract, skin injury	E.g., Cancer, leukemia, hereditary effects

Once the realization that radiation exposures could cause stochastic effects evolved, the principal of ALARA (As Low As Reasonably Achievable) was recognized as being important in the protection of workers, the public and the environment from radiation exposure.

ALARA is a concept that seeks to keep all doses of radiation as low as possible. Controls are expected to be implemented by taking into account social and economic factors.

Social and Economic Factors

The "social and economic factors" to be taken into account include the costs of reducing the doses from a given level to a lower level, bearing in mind the expenditures that are generally made for reducing a unit of occupational or public risk associated with other industrial and social activities. Factors such as the possible loss of employment if the dose had to be reduced to such low levels that an operation had to be discontinued should also be considered. Regardless of economic and social considerations, however, it is mandatory that no person be exposed to more than the regulatory dose limits.

In practice, both individual and collective doses should be considered when deciding what levels of dose are as low as reasonably achievable for a given operation. Efforts devoted solely to minimizing collective dose could result in some workers approaching dose limits early in the dosimetry year, whereas operational needs and manpower planning considerations might require that the doses of all workers be kept well below the limits early in the year so that additional dose could be received during necessary work with radiation during the remainder of the year.

13.0 RECORD OF REVISIONS

Date	Author/Editor	Change	Version
September 2020	Greg Friday	• Added an "Introduction" section that introduces ALARA • Added an ALARA Appendix	Radiation Safety Program_v.2.0_SEP2020
September 2019	Dhananjai Borwankar and Greg Friday	• Training moved to LEARN • Added section 12.0 Record of Revisions	Radiation Safety Program_v.1.0_SEP2019
September 2018	Dhananjai Borwankar and Greg Friday	• Formatting changes	Radiation Safety Program_v.1.0_SEP2018