Queen's University Radiation Safety Policies and Procedures Manual 2022

Radiation Protection Program Document
Department of Environmental Health and Safety

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Queen's University
Radiation Safety
Policies and Procedures Manual 2022

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The intent of the Radiation Safety Program at Queen's University, and the purpose of the Queen's Radiation Safety Policy and Procedures Manual, is to guide personnel in how to work safely with radioactive substances and devices. The goal is to prevent or reduce radioactive exposures, to protect those outside the laboratory from the harmful effects that a release of the radioactive material might have, and to comply with relevant legislation. The University is committed to ensure that all exposures are kept as low as reasonably achievable. The purchase, transfer, use and disposal of nuclear substances is strictly controlled by the Canadian Nuclear Safety Commission (CNSC), which has issued Queen's University a Consolidated Nuclear Substances and Radiation Devices Licence. This licence authorizes the University to issue Internal Radioisotope Permits for the use of nuclear substances on campus.

The CNSC allows licensing exemptions for various nuclear substances such as naturally occurring radioactive material, smoke detectors, and sources below the exemption quantity. Queen's University does not maintain controls over non-licensable nuclear substances unless otherwise required by the regulations for such activities as transportation, import/export, and where international safeguards regulations apply.

This Manual will guide you in how to fulfill the requirements of the Canadian Nuclear Safety Act and all its regulations, including the conditions of Queen's Consolidated Licence.

It is recommended that you read the sections about the Radiation Safety Committee and the University Radiation Safety Officer so that you understand the roles and responsibilities and authority of these bodies and how they may assist you in your program that involves radioactive materials, X-rays or lasers.

Basic information regarding nuclear physics, as well as the policies and procedures for the use of radioactive materials at Queen's is presented in the Radiation Safety Training course which can be accessed through the Environmental Health and Safety Website under Training or by contacting the RSO. Information about specific radioisotopes is presented in a number of the appendices to this manual.

This manual is reviewed by the Radiation Safety Committee on an annual basis and revisions are made as deemed necessary.

Radiation Safety Policy

The Principal of Queen's University has appointed the University Radiation Safety Committee to carry the advisory responsibility for the overall operation of the University Radiation Safety Program. The details are included in the Terms of Reference of the University Radiation Safety Committee (hereafter referred to as the Committee).

It is the policy of Queen's University that all activities involving ionizing radiation or radiation emitting devices be conducted so as to keep hazards from radiation to a minimum.

Persons involved in these activities are expected to comply fully with the Canadian Nuclear Safety Act and all its regulations, with the Occupational Health and Safety Act and its regulations.

Scope

The Radiation Safety Policy and Procedures will apply to all activities which utilize radioisotopes and radiation emitting devices including:

1. University teaching programs and University research projects;
2. research involving the use of University facilities;
3. research funded by other agencies through the University;
4. any other projects that the Committee deems are within the jurisdiction of the Committee.

Authority and Responsibilities of the University Radiation Committee

Authority

The Committee has authority from the Principal to recommend:

1. the procedures for the authorization and control of the use of radioisotopes and radiation producing devices at the University in compliance with the Canadian Nuclear Safety Act, the consolidated or individual licences issued by the Canadian Nuclear Safety Commission (CNSC) and the Regulation Respecting X-ray Safety made under the Occupational Health and Safety Act.
2. the **suspension, when necessary, of the use of any radioisotope or radiation producing devices at the University**, regardless of the source of authorization.

Responsibilities

The Committee is responsible for:

1. developing University policy with respect to the safe use of radioactive materials and techniques capable of producing hazardous emissions, including: X rays, lasers and electromagnetic radiations, such as microwave and other potentially hazardous emissions such as ultrasound

2. advising the University, its faculties, departments, cross appointees and researchers of the Committee's policy and of the special requirements relating to research and transport of the above materials and devices

3. making recommendations to the University, through the Vice Principal (Operations and Finance), concerning the actions to be taken on specific aspects of radiation matters as they arise

4. advising the development of appropriate procedures for the handling of emergency situations relating to radiation within the University

5. providing at appropriate intervals to the University and to external agencies, as required, reports on

    i. situations and activities involving radiation
    ii. all radiation incidents and accidents that require reports on safety aspects

6. acting as a resource body for the University and its staff to provide

    i. dissemination of up to date information regarding current CNSC and other government regulations concerned with licencing, containment facilities, training procedures and other related matters as they arise
    ii. arrangement for providing monitoring facilities, through the office of Environmental Health and Safety, for both personnel and equipment
    iii. a library resource
    iv. instructional services in radiation safety technology
    v. relevant planning advice for new construction and modification of University buildings

7. providing liaison with the Radiation Committees of the Hospitals, Royal Military College and other local institutions regarding items of mutual concern.

Radiation Safety Officer (RSO)

RSO Authority

1. The Radiation Safety Officer (RSO) works under the advice of and reports to the Chair of the Radiation Safety Committee (RSC) and the Director of Environmental Health and Safety on all matters pertaining to radiation safety. The RSO is to assume control in any emergency involving radiation hazards and to take such actions as may be necessary to ensure the safety of personnel, property, and equipment, and report these actions at the earliest possible time to the Chair of the RSC. **The RSO has the authority to shut down, temporarily, any process or laboratory that he or she considers to be in violation of university policy or CNSC regulations.**

2. The RSO has the authority to enter research areas to conduct tests required for monitoring safe handling and disposal of radiation sources.

3. The RSO is required to report to the RSC or to its Executive, at the discretion of the Chair, on his or her activities, including advice given and actions taken or recommended.

RSO Responsibilities

The RSO is responsible for:

1. administering the policy of the University and its Radiation Protection Program and acting as liaison with the CNSC and other regulatory agencies.

2. advising the RSC on new and proposed Federal and Provincial legislation or items which may affect the use of radiation on campus.

3. preparing renewal applications to the CNSC and preparing any other application as required by the CNSC.

4. preparing the annual reports to the CNSC and preparing any other reports as required by the CNSC.

5. serving as the RSC representative when plans are being formulated for new radiation laboratory facilities or alterations to existing laboratories.

6. providing at appropriate intervals to the University and to external agencies, as required, reports on
   i. situations and activities involving radiation.
   ii. all radiation incidents and accidents that require reports on safety aspects.

7. notifying the CNSC of any condition listed in the Department of Environmental Health and Safety's *SOP-Radiation 04 Notification to CNSC*.

8. developing and implementing administrative controls or procedures to ensure radiation safety and compliance with regulatory requirements.

9. supervising the technical and support staff of Environmental Health and Safety in the matter of radiation safety activities.

10. distributing documents outlining policies and procedures which detail the acquisition and handling, control and disposal of radioactive materials.

11. reviewing all applications for Radioisotope Users' Permits. The RSO will approve all Permits unless they are of an unusual or complex nature. These permits applications will be submitted, with recommendations, to the Radiation Safety Committee for consideration.

12. maintaining files on all activities involving radioactive materials and sources of hazardous radiation. These files include lists of designated laboratories, permits, permit approved isotopes with limits and users.

13. providing and supervising educational programmes on radiation safety for university personnel

14. reviewing orders for the purchase of radioactive materials and other radiation sources and ensuring that they are in compliance with the CNSC licence conditions and University policies.

15. ensuring that personnel who accept/receive radioisotopes from public carriers are trained as to the proper handling of packages containing nuclear substances through the completion of the University's Radiation Safety Training Course.

16. maintaining a campus-wide inventory, including the Waste Transfer Station, of radioactive materials by permit. This will be updated regularly by checking purchase orders and disposal records for radioactive material and by cross-reference with inventories held by users, as necessary.

17. supervising a radioactive waste collection and disposal service in accordance with established procedures. This will include assuming responsibility for the proper handling of any radioactive substance which cannot be identified as the responsibility of another individual or Department.

18. administering the Health Canada dosimeter service and maintaining all necessary records

19. inspecting and surveying laboratories and other workplaces where radioisotopes, or any other radiation emitting devices are used on an annual basis.

20. ordering and supervising decontamination procedures when radiation accidents are reported.

21. Ensuring a notice of the university's Nuclear Substance and Radiation Device Licence is posted in a conspicuous location within all listed licence location on said licence.

University Radiation Permits

Permits for the use of radioisotopes and radiation emitting devices will be issued by the Committee to qualified persons under the Consolidated University Licence granted by CNSC. These permits do not permit experiments directly involving human subjects where more than an exemption quantity is used and unless specifically authorized.

Details of how to obtain a University Permit for the use of radioisotopes and radiation emitting devices are presented later in this manual. Contact the RSO if you require more information regarding the application for a new Queen's University Radiation Permit.

Internal Review

All laboratories shall receive an inspection by the RSO on an annual basis.
Copies of the Inspection checklist are mailed to the Permit Holder. All areas of non-compliance must be corrected, and written notice of corrective action taken must be sent to the RSO.

Responsibilities of the Permit Holders and Delegation of Responsibility

Permit holders must have experience in the handling of radiation emitting sources and materials.

Permit Holder Responsibility

Each permit holder is responsible for:

1. ensuring that the conditions stated in the radioisotope permit are fulfilled

2. arranging for adequate facilities, equipment, instruments, supervision and instruction in compliance with the University's radiation protection policies. The normal sources of financing research support, both inside and outside the University, should be solicited

3. establishing a laboratory procedure to ensure that when working with an open source
    i. survey measurements have established that external radiation and contamination levels are within permissible limits
    ii. radiation sources are properly labelled and stored
    iii. experiments that will be in progress after normal working hours will be properly attended

iv. each laboratory is secured against unauthorized access

4. reporting all radiation incidents to the RSO in accordance with Radiation Committee Policy and Procedures (details of when to report in Procedures for Spills or Ingestion of Radioisotopes, Appendix 1)

5. report to the RSO of any situation in which they believe there may be:
   i. significant increase in the risk to the environment or health and safety of another person
   ii. threat to security or a breach of security
   iii. failure to comply with Act or Regulations
   iv. any act of sabotage, theft loss or illegal use of a nuclear substance
   v. any release to the environment above permit levels

6. instructing all workers, prior to employment in radiation laboratories, to make them aware of the potential hazards of radiation, including genetic effects and ensure that all workers have completed the University Radiation Safety Training Course.

7. maintaining an inventory of radioactive materials used in his or her research projects, and ensuring that the possession limits are not exceeded

8. keeping records of the disposal of radioactive material

9. ensuring that all persons wear appropriate protective equipment, radiation monitoring badges and/or pocket dosimeters as required

10. allowing only authorized persons to enter rooms that are specified as restricted areas

11. ensuring that the RSO has an up to date listing of all radioisotope users authorized by the permit

12. posting of warning signs and labels as required by the Canadian Nuclear Safety Commission Regulations and the Radiation Committee Policy and Procedures.

Delegation of Responsibilities by Permit Holders

There may be circumstances where the permit holder is not listed as an authorized user or else is absent from the laboratory for a prolonged time. In both these circumstances, the responsibilities of the permit holder, as set out above, must be delegated. Permission of the Radiation Safety Committee must be obtained before the responsibilities can be delegated and the Head of the Department must agree to the proposed delegation.

Some responsibilities of a permit holder may be delegated to any qualified person who is an employee. These responsibilities are of an administrative nature and include items 6 - 11 in the list of responsibilities of a permit holder. Items 1 - 5 from the list of responsibilities require financial and professional decisions from an employee who can be held accountable. In most circumstances, this could only be a permit holder who works as an authorized user in a laboratory, or a technically qualified employee as defined below. (Every application for a permit requires the applicant to name the persons who will be using the radioactive materials, the authorized users.)

The Radiation Safety Committee will follow the general policy outlined below to reach a decision concerning the delegation of responsibilities by a permit holder. Each request will be considered on its own merits and a final decision will be made only after taking extenuating circumstances into account.

All responsibilities of a permit holder may be delegated to a technically qualified employee of the University who also holds either a letter of appointment from the Principal or is an employee who would qualify as an "Internal Applicant" as defined by Human Resources. In many circumstances, these conditions would exclude technicians and assistants paid from research grants or contracts. Graduate and undergraduate students are also excluded.

Radioisotope Workers' Responsibilities

Each individual who uses radioactive material is responsible for complying with the Radiation Committee Policy and Procedures, and with those established for the permit holder's radioisotope permit.

1. Prior to working in radiation laboratories, individuals must obtain **training** by completing the University Radiation Safety Training Course.
2. Learn about the specific radiation hazards and associated procedures for the laboratories in which they will work.
3. Each year complete the Annual Radiation Refresher Training Course.

Workers must inform their supervisor of any situation in which the worker believes there may be:

1. significant increase in the risk to the environment or health and safety of another person
2. threat to security or a breach of security
3. failure to comply with Act or Regulations
4. any act of sabotage, theft loss or illegal use of a nuclear substance
5. any release to the environment above permit levels

Nuclear Energy Worker Designation

Queen's University currently does not have a written policy and procedure to designate Nuclear Energy Workers.

There is no reasonable probability that a worker may receive a dose of radiation that is greater than the prescribed limits for the general public during the course of employment at Queen's University. Although The CNSC has set conservative limits, care should be taken to avoid unnecessary exposures. Appendix 19 of this manual shows the dose limits for members of the public.

Currently all radiation workers at Queen's University are classified as **Non-Nuclear Energy Workers**

Radiation Safety Training

All users of radioactive sources must take the Queen's University full radiation safety course. Copies of the slides for the Queen's University Radiation Safety Course are provided for all who attend the in-person lecture. The participants have not finished the course until they successfully complete an online test. Certificates of completion are provided to those who achieve 80% or greater.

All authorized users must complete an annual refresher quiz located online. The refresher slides are provided to the users to review prior to taking the refresher quiz. The quiz covers different aspects of radiation safety each year. Any new policies or CNSC requirements are also covered in the annual quiz.

A less in-depth radiation awareness course, explaining the hazards, is given to all trades and custodial staff.

X-ray Equipment Users

Users of X-ray equipment are responsible for complying with the University Radiation Committee's Policy and Procedures, the Occupational Health and Safety Act, the Ontario Regulation for X-ray Safety (Reg. 263/84), and also the owner's instructions regarding the use of the X-ray producing equipment.

The Queen's SOP for X-Ray Safety, SOP-Radiation-03, must be reviewed and followed, and all X-ray equipment must be registered using the forms available in the Radiation/X-Ray section of the Environmental Health and Safety Website.

Laser Equipment Users

Users of laser equipment are responsible for complying with the University Radiation Committee's Policy and Procedures, the Occupational Health and Safety Act and Regulation, and also the owner's instructions regarding the use of the laser equipment.

The Queen's SOP for Laser Safety, SOP-Radiation-03, must be reviewed and followed. All Class 3b and 4 lasers must be registered using the form available in the Radiation/Laser Safety section of the Environmental Health and Safety Website.

Operational Practices for Working with Radioisotopes

General guidelines and precautions for working with specific radionuclides are provided in Appendix 2.

Other useful information when planning your work is provided in subsequent appendices including:

- Measurement Units Conversion Table (Appendix 3)
- Exemption Quantities (Appendix 4)
- Annual Limit of Intake (ALI) for typical radionuclides (Appendix 5)
- Radioisotope Information for Specific Radioisotopes (Appendix 6)
- Classes of Nuclear Substances (Appendix 7)

To reduce the possibility of accidental ingestion of radioisotopes the following rules for operational practices must be observed by all personnel:

1. No smoking, eating or storage of food in any area containing radioactive material.

2. No mouth pipetting of solutions containing radioactive material.

3. Whenever practical, the user should perform a trial experiment using stable or low activity material to establish the adequacy of the procedures and equipment.

4. Prior to performing an operation on a source of radioactive material, radiation levels will be measured. Handling tongs or a suitable remote handling device must be used for handling any source or container which emits, at contact, a dose rate in excess of 10 uSv/hr (1 mrem/hr).

5. When performing operations that might produce airborne contamination (e.g. boiling, evaporating, sanding or grinding), work shall be carried out in a fume hood.

6. A glove box should be used for work involving dry radioactive powdered material.

7. Whenever possible, work with radioactive material shall be carried out using trays lined with disposable absorbent material.

8. When hand or clothing contamination is possible, protective gloves and clothing shall be worn.

9. After handling unsealed radioactive material, hands shall be washed before leaving the laboratory and clothes, shoes and hands should be monitored for contamination.

10. Objects and equipment used in work with radioactive material shall not be used for other purposes and shall be surveyed for contamination prior to removal from the laboratory.

Radiation Detection Equipment

The RSO makes annual arrangements for the calibration of the radiation detection equipment mentioned below to ensure compliance with the University's consolidated licence. All other instruments used under the Queens University licence must also be calibrated annually by a qualified service provider to ensure that the calibration is conducted in accordance with the CNSC Application Guide - Appendix Z "Regulatory Expectations for Calibration of Survey Meters". A copy of all calibration records is kept and maintained within the Department of Environmental Health and Safety.

Personal Dosimetry

Permits that use high energy beta or gamma isotopes have the following condition included in their internal permit: Whole body dosimeters are required for all radioisotope handlers in the laboratory. Wrist or Finger Monitors; Safety Glasses; Shielding Hand exposure to radiation should be determined where quantities of 0.1 to 1 mCi of 32P is handled in a single vessel. Where quantities in excess of 1 mCi are handled in a single vessel, wrist or finger monitors must be worn, and safety glasses must be worn, and the radioisotope must be enclosed within a plastic shield which is at least 6 mm thick.

Dosimetry badges are obtained through Health Canada. Badges are mailed directly to laboratory; however, all reports are mailed to the RSO who maintains a campus wide database to track all exposures. Copies of the reports are held by the Environmental Health and Safety department. The RSO reviews all doses attributed to Queen's personnel on the Health Canada whole body dosimeter *"Exposure Reports"*.

Any quarterly dose received at or above 250 uSv in a given quarter triggers a full investigation by the RSO. These investigations are documented and kept on file within the Environmental Health and Safety department.

OSL dosimeters do not monitor low energy beta emission isotopes (e.g. ^{3}H, ^{14}C or ^{45}Ca) therefore workers using such isotopes may be required to submit biological samples;

Appendix 19 lists regulatory dose limits and Appendix 18 lists Radiotoxicity of Radioisotopes.

Purchasing Radioisotopes

All orders for radioisotopes will be approved and placed directly with the suppliers only by authorized members of the Department of Environmental Health and Safety.

In order to prevent delays and to keep the ordering as simple as possible, while at the same time maintaining a system of control which the CNSC demands, investigators are requested to place their orders in the following manner:

1. Place orders through the Queen's acQuire e-procurement system.
2. Permit number must be included in the requisition under the comments section.
3. Under the general section of the purchase requisition, select the check box ***"Do Not Send PO to Vendor".***
4. Select category Lab supplies, radiochemicals.
5. Once the purchase requisition is received, the RSO determines if the university is licenced for the isotope, and if the current requested activity of the isotope plus the current inventory of the particular isotope at the university is less than the maximum permissible activity of the particular isotope on the licence. This inventory information is found in the university radioactive material database that is maintained by the RSO. The RSO approves or denies the requisition request in acQuire. If the maximum permissible activity of the isotope is exceeded, the requested order is denied and an amendment to the licence may need to be requested by the RSO.
6. If approved, suppliers will be asked to deliver directly to the investigator's department and to forward invoices to the Purchasing Department.
7. Arrangements for payment will be made directly between the purchaser and the Purchasing Department.
8. Confirmation of the order is provided to the ordering party and an expected time of delivery is also provided.
9. Notification of the radioisotope's arrival is given to the RSO once it (they) is (are) received at its destination at Queen's.
10. RSO adds the isotope to the official Queen's University radioisotope inventory.

Receipt of Packages

The proper method of receiving packages is taught in the University's Radiation Safety Training Course. For a review of the method and package labelling see Appendix 20.

Transferring Radioactive Materials

If you wish to acquire a nuclear substance or radiation device from any location here at Queen's or from a location outside the university, first contact the Radiation Safety Officer (RSO) to ensure that the appropriate permit is in place, and that the central radiation inventory is adjusted appropriately.

The RSO maintains Transportation of Dangerous Goods - Class 7 certification at all times and must be involved in all radioactive transfers occurring internally as well as nuclear material or radiation devices going to or from other institutions.

The RSO strictly adheres to the "Packaging and Transport of Nuclear Substances Regulations, 2015" and "IAEA Safety Standard: Regulations for Safe Transport of Radioactive Material, 2018 Edition" when packaging, shipping, or transporting nuclear substances or radiation devises. Internal Radiation Protection Program procedure SOP-RADIATION-05 also describes the TDG-Class 7 shipping steps in detail.

All transfer records are kept and maintained within the Department of Environmental Health and Safety.

Record Keeping

All records and reports must be available for inspection at the site. All records and reports required under the regulations will be completed, maintained and kept in accordance with the CNSC regulations and provided to the CNSC upon request.

Records may not be disposed of until permission has been received from the RSO. The RSO must give the CNSC a 90-day notice prior to disposal of prescribed records.

Inventory

Each permit holder must designate people in the laboratory who are authorized to place orders with online ordering system. The only people at Queen's who are permitted to approve purchase orders through the on-line ordering system and to order radioisotopes from suppliers, are the personnel within the Department of Environmental Health and Safety. All suppliers receive a letter from the RSO included with the University's licence, stating the only people able to place a radioisotope order on behalf of Queen's University.

When a radioactive order is placed within the aQuire purchasing system, the following is verified: the isotope is allowed under the licence, permit restrictions and the possession limit and annual limit have not been surpassed.

The RSO is involved in all radioisotope purchases, transfers and disposals at Queen's and maintains a database showing all nuclear substances coming into, moving within, or leaving the university. The inventory information collected by the RSO allows his to ensure the university's inventory does not exceed CNSC licence limits.

Inventory records must be kept using the standard Inventory Form (Appendix 9).

1. One record is required for every vial of isotope ordered.
2. Forms must be filled out upon receipt of product.
3. A copy of the purchase order, packing slips, Transport of Dangerous Goods documents and any other documents associated with the order must be attached to the inventory form.

Flow Sheets

The entire record-keeping process is linked to the development of a flow sheet. The flow sheet details the step-wise destinations of the radioisotope, beginning with the amount of product used and ending with an accurate record of the waste(s) produced.

A flow sheet must be developed and kept for each and every procedure that is to be carried out in the laboratory.

In most cases the protocol will have to be investigated only one time in a step-wise basis so that the flow sheet can provide a record of the movement of isotopic activity through the procedure. **Direct measurements (printouts must be kept) should be made of the activity of all side and end products and must be detailed in writing.** Where appropriate, manufacturers specifications for percentage of incorporation may be used, however, direct measurements are generally more accurate.

Examples of flow sheets are provided (Appendix 10).

Waste Logs

Waste logs must be kept to detail all wastes disposed of via Environmental Health and Safety.

1. Separate logs should be made for individual bags of waste.
2. Information contained in the waste log should be cross-referenced with information from the flow sheet.
3. Logs must be sufficiently detailed so that the activity of the contents of any given bag of waste can be accurately demonstrated.

High Level Lab Exit Logs

To ensure that contamination is not spread from high level radioisotope laboratories a record of contamination checks upon exit is required (Appendix 15).

Disposal of Radioisotopes

Radioactive material is the responsibility of the holder of the permit while it is in his or her possession. The methods for radioactive waste disposal will be outlined specifically on the permit.

All radioactive waste is disposed of via the Department of Environmental Health and Safety.

All permit holders will keep up-to-date records of the purchases, uses, storage, and disposal of all radioactive material used in their laboratories. (see section on Record Keeping for details).

Wastes shall be handled as follows:

1. radioisotopes with short half lives must be safely stored until they can be disposed of as required. Spreadsheets are available on the EH&S website to calculate the decay of certain isotopes stored as aqueous waste.

2. other radioisotopes must be safely stored until they are disposed of by an approved method. Environmental Health & Safety has a limited storage space. Please ask the RSO to arrange for the use of this storage space.

General Radioactive Material Disposal Methods

1. Laboratory personnel will package dry waste and/or scintillation solvent in such a way to prevent contamination to handlers and will ensure that the activity measured at surface is less than 0.1 mSv/hr gamma or 1 mSv/hr beta (1 mSv=100 mrem).

2. Fill out the approved disposal tag (yellow) and attach one to each package to aid in identification. Contact the RSO if you require yellow disposal tags.

3. When radioactive wastes that cannot be dealt with by methods outlined above, the permit holder is responsible for ensuring that wastes which may be hazardous apart from their radioactivity can be disposed of safely and in accordance with any regulation governing the disposal of such substances.

    i. The presence of these wastes should be brought to the attention of the RSO.
    ii. All waste material should be packaged carefully for disposal and should not present a hazard to anybody who may handle the containers (e.g. articles such as broken glass and used syringes must not be able to puncture the package).

4. Dry solid wastes originating in the laboratory consist of a wide variety of combustible and non combustible materials. All solid waste must be disposed of through the Department of Environmental Health & Safety.

5. Aqueous radioactive waste must be stored in a separate secure container.

Follow the Disposal Procedures in Appendix 11.

All open source radioactive waste disposed of at Queen’s University by EH&S personnel or by licenced disposal contractors is logged within the radiation files of the Environmental Health and Safety Department. The RSO monitors all radioactive disposals made and compares the totals against the limits set within the University's licence.

All sealed source radioactive disposals at Queen's are made under the observation of the RSO and are carried out through the university's hazardous material disposal contractor who holds a licence with the CNSC.

Flammable Liquid Radioactive Wastes

A significant proportion of flammable liquid radioactive wastes produced on campus has been liquid scintillation solvents. Although the radiation health hazard from these solvents is minimal they do present other hazards common to organic solvents. Scintillation liquid shall be disposed of according to Appendix 11.

Animal Carcasses

Animal carcasses containing radioisotopes may be disposed of as:

1. non-radioactive carcasses, provided that the activity per kilogram of body weight is less than one scheduled quantity as shown in Appendix 4. After appropriate labelling as radioactive carcasses, the animals containing radioisotopes may be taken from the secure place and disposed of through the normal system.

2. carcasses containing short lived radioisotopes shall be placed in sealed plastic bags and stored in a refrigerated secure place in the laboratory until the levels of activity permit disposal as non-radioactive carcasses.

3. carcasses containing radioisotopes with longer half-lives at levels greater than one scheduled quantity per kilogram are to be stored in a refrigerated secure place until arrangements can be made with the RSO for their disposal.

Contamination Control

All laboratory areas where radioisotopes in use must be monitored at least weekly for removable surface contamination and records must be kept of the results. Both positive and nil readings must be recorded. If the removable contamination is greater than either 3 times background or 3 Bq/cm2 averaged over an area not exceeding 100 cm2 then the surfaces must be decontaminated and remonitored.

Wipe tests must be used for low energy radioisotopes such as H-3, C-14, S-35, Ca-45, I-125. An appropriate survey meter may be used for more energetic radioisotopes such as P-32 & Na-22.

Wipe tests must be done if both low and high energy radioisotopes are being used.

Contamination monitoring is required only if radioisotopes are in use. Please indicate periods of inactivity on your contamination control log.

A general description of the requirements for monitoring contamination is provided below. Follow the detailed procedure for monitoring contamination (Appendix 12).

Open Sources

All laboratories must be monitored weekly for removable surface contamination when open source radioisotopes are in use. A written record of results will be maintained by the permit holder. Monitoring systems will include either direct methods or indirect methods or both.

Sealed Sources

Leak testing of sealed sources is required under CNSC regulations to ensure that a sealed source has not developed defects, has been damaged or has degraded so as to present an unrecognized radiological risk to persons using or working near the source.

Only Queen's University staff specifically trained to do sealed source leak testing by the Radiation Safety Officer are permitted to conduct these tests in accordance with CNSC REGDOC 1.6.1 "Licence Application Guide, Appendix AA: Regulatory Expectations for Leak Testing Sealed Sources". An example of a sealed source leak test certificate can be found in Appendix 13.

Sealed Source Regulatory Requirement:
The regulatory requirement to conduct regular leak testing of sealed sources, including their frequency and detection level, is specified in section 18 of the Nuclear Substances and Radiation

Devices Regulations and in section 19 of the Class II Nuclear Facilities and Prescribed Equipment Regulations:

"(1) Every licensee who possesses, uses or produces either a sealed source containing 50 MBq or more of a nuclear substance or a nuclear substance as shielding shall, at the following times, conduct leak tests on the sealed source or shielding using instruments and procedures that enable the licensee to detect a leakage of 200 Bq or less of the nuclear substance:

- (a) where the sealed source or shielding is used after being stored for 12 or more consecutive months, immediately before using it;
- (b) where the sealed source or shielding is being stored, every 24 months;
- (c) where an event that may have damaged the sealed source or shielding has occurred, immediately after the event; and
- (d) in all other cases,
  - (i) where the sealed source or shielding is located in a radiation device, every 12 months, and
  - (ii) where the sealed source or shielding is not located in a radiation device, every six months.
- (e) Subsection (1) does not apply in respect of a sealed source that is
  - (a) gaseous;
  - (b) contained in a static eliminator that has been retained by the licensee for less than 15 months;
  - (c) exempted under section 5, 6, 8 or 8.1; or
  - (d) used or stored underwater in a nuclear facility that is equipped with a device capable of detecting waterborne contamination of 200 Bq or less of a nuclear substance.
- (f) Where a licensee, in the course of conducting a leak test on a sealed source or on shielding, detects the leakage of 200 Bq or more of a nuclear substance, the licensee shall
  - (a) discontinue using the sealed source or shielding;
  - (b) discontinue using the radiation device in which the sealed source or shielding is located or may have been located;
  - (c) take measures to limit the spread of radioactive contamination from the sealed source or shielding; and
  - (d) immediately after complying with paragraphs (a) to (c), notify the Commission that the leakage has been detected."

Decontamination

Good working habits and good housekeeping will prevent most contamination incidents and circumvent the need for decontamination. For example, disposable absorbent bench coverings and working on trays will limit the spread of contamination.

Decontamination of Work Areas and Equipment

When decontamination of work areas or equipment is required, the procedures detailed in Appendix 1 should be used.

Personnel Decontamination

The RSO must be informed of all cases of personal contamination immediately. Also refer to "Appendix 1 – Emergency Procedures" in the case of skin contamination events.

1. If a person is suspected of being contaminated, locate the contaminated area with a survey meter, if possible.

2. If external contamination is present, follow one of the two procedures below:

    a. If the **skin is not broken**, flush copiously with water and then wash the area with a mild nonabrasive detergent or soap. Work the lather into the contaminated area by rubbing gently for about 5 minutes and rinsing thoroughly under running lukewarm water. Repeat as if necessary.

    b. **If the skin is broken** close to the contaminated area, swab the area with wet swabs taking care not to spread the activity into the wound or over the body.

Obtaining a Queen's Permit

The purchase, transfer, use and disposal of nuclear substances is strictly controlled by the Canadian Nuclear Safety Commission (CNSC). Queen's University has been issued a Consolidated Nuclear Substances and Radiation Devices Licence by the CNSC. This licence authorizes the University to issue Internal Radioisotope Permits for the use of nuclear substances on campus.

New Permits

Complete in full the form "Application for a Radioisotope User's Permit" (Appendix 8) and forward the form to the RSO.

All personnel in the lab must be listed on the permit as an approved user.

A permit is not required to use the SLOWPOKE 2 facilities at R.M.C. However radioactive material generated by the facility may not be brought back to the University unless the user has a valid Radioisotope User's Permit.

The application will be reviewed by the RSO. Complex applications may be forwarded by the RSO to the Radiation Safety Committee for review/approval.

Once approved by the RSO/Committee, a permit will be issued, signed by the RSO.

i. Permits will be issued with an expiry date of January 31 in the year following the application.

ii. One copy of the approved permit will be forwarded to the applicant and another copy will be filed by the Department of Environmental Health and Safety.

iii. A copy of the permit must be posted in every laboratory listed on the permit.

NOTE: Strict adherence to the conditions of approval for each and every permit is mandatory. Failure to comply can result in suspension or cancellation of individual permits and may also seriously jeopardize the continuance of the University's consolidated licence.

It should also be mentioned, written authorization must be obtained from the CNSC prior to issuing any internal authorization permit for any work requiring the use of more than 10,000 exemption quantities of a nuclear substance at a single time.

The requirements for setting up the laboratory are summarized in Appendix 14.
Laboratory Classifications are defined in Appendix 17.

Amendments to Permits

Amendments may be initiated by e-mailing the RSO.   Major amendments may require the approval of the Radiation Safety Committee.

Renewal of Permits

Permits must be renewed in advance of the expiry date to be specified on the permit.

A renewal package to each permit holder not less than four weeks prior to the expiry date.

i. This form must be signed by the permit holder and also by the Department Head.
ii. The permit holder shall forward a completed "Application for a Radioisotope Permit Renewal" to the Department of Environmental Health and Safety.

Renewal without major amendments may be granted by the RSO.

Renewal with major amendments may be referred for approval to the Committee.

Laboratory Decommissioning

Before a Permit Holder leaves the University, moves their laboratory, or wishes to cancel their internal permit, their laboratories must be decommissioned as per Environmental Health and Safety Policy SOP-LAB-04 (Laboratory Decommissioning).

Refer to Appendix 16 for contamination control criteria.

General Precautions Following Spills or Ingestion of Radioisotopes

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

Definition: *A Minor spill is typically less than 100 exemption quantities of a nuclear substance.*

1. Wearing protective clothing (lab coat, or disposable coveralls) and appropriate disposable gloves, clean up the spill using absorbent paper and place it in a plastic bag for transfer to a labelled waste container.

2. Avoid spreading contamination. Work from the outside of the spill towards the centre.

3. Wipe test or survey for residual contamination as appropriate. Repeat decontamination, if necessary, until contamination monitoring results meet the Nuclear Substance and Radiation Devices licence criteria.

4. Check hands, clothing and shoes for contamination.

5. Report the spill and clean-up to the Supervisor.

6. Report the spill and clean-up to the permit holder and the Radiation Safety Officer.

7. Record spill and clean-up and decontamination monitoring details. Adjust inventory and waste records appropriately.

Major Spills

Definition: *A Major Spill involves more than 100 exemption quantities, or contamination of personnel, or release of volatile material.*

Major spill procedures should be implemented whenever minor spill procedures would be inadequate.

If an overexposure may have occurred that is in excess of applicable radiation dose limits, the Radiation Safety Officer shall, upon becoming aware of the situation, immediately contact the CNSC to submit a preliminary report.

1. Clear the area. Persons not involved in the spill should leave the immediate area. Limit the movement of all personnel who may be contaminated until they are monitored.

2. If the spill occurs in a laboratory, leave the fume hood running to minimize the release of volatile radioactive materials to adjacent rooms and hallways.

3. Close off and secure the spill area to prevent entry. Post warning sign(s).

4. Notify the Radiation Safety Officer (RSO) and permit holder immediately. The RSO will subsequently notify the CNSC immediately that a major spill has taken place.

5. The RSO will direct personnel decontamination and will decide about decay or clean-up operations.

6. In general, decontaminate personnel by removing contaminated clothing and flushing contaminated skin with lukewarm water and mild soap. Do not scrub skin vigorously.

7. Follow the clean-up procedure for minor spills (if appropriate).

8. Record the names of all personnel involved in the spill. Note the details of any personal contamination.

9. The RSO will arrange for any necessary bioassay measurements.

10. Submit a full report along with a copy of the contamination monitoring results to the RSO

11. The RSO must submit a full report to the CNSC within 21 days of the occurrence

Personal Radioactive Decontamination:

- The Radiation Safety Officer (RSO) must be informed of all cases of personal contamination immediately.
- The below CNSC document, "DNSR article – CNSC Expectations for Licensee Response During Skin Contamination Events" shall be followed in all instances of skin contamination.

CNSC Expectations for Licensee Response During Skin Contamination Events

This article describes the Directorate of Nuclear Substance Regulation's (DNSR) expectations for licensee response to skin contamination incidents. Experience gained over the past several years has shown that most skin contamination incidents, if detected promptly, actually result in relatively low extremity doses. Consequently, continued reporting of incidents which do not result in a significant dose would be unnecessarily burdensome for both licensees and the regulator. As a result, the DNSR is implementing a revised reporting scheme: only incidents in which the dose exceeds 10 percent of the corresponding dose limit must be reported to the licensing officer. In addition, this article provides a standardized method for evaluating skin dose, including detection screening levels to assist licensees in evaluating whether or not a particular incident must be reported.

Irrespective of the requirement to report, all licensees are required to document, record and investigate every skin contamination event to ensure work practices are optimized and to minimize the probability of repeat occurrences.

Response to skin contamination events can be divided into three parts:

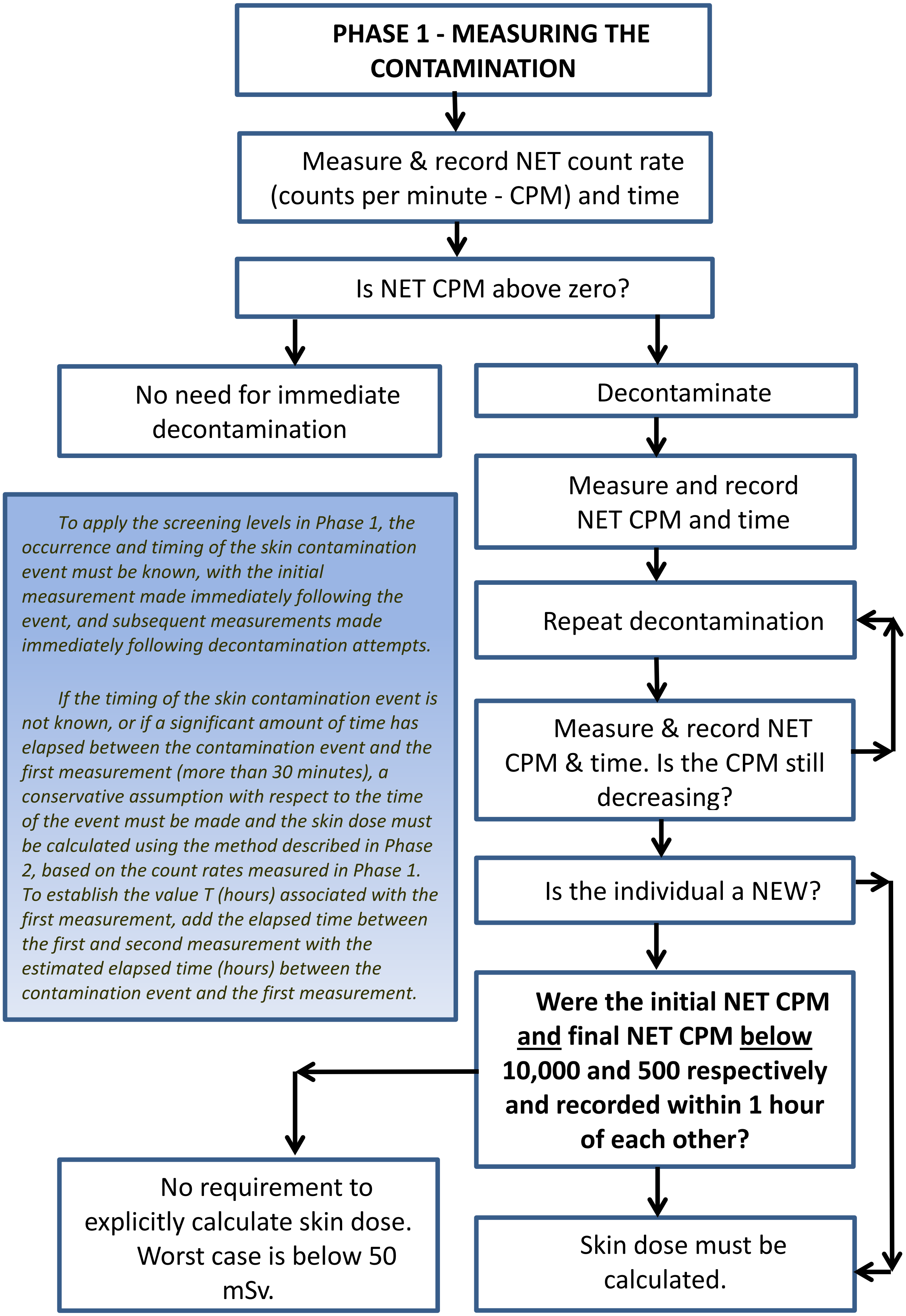
- Phase 1 – Measuring the contamination and decontaminating the skin
- Phase 2 – Calculating the skin dose
- Phase 3 – Reporting to the CNSC, if necessary

Reporting skin contamination events to the CNSC is only required for the following circumstances:

1. If a nuclear energy worker (NEW) was calculated to have received an extremity (skin) dose above 50 mSv.
2. If a Non-NEW was calculated to have received an extremity (skin) dose above 5 mSv.

The flow diagrams and appendices on the following pages provide step-by-step instructions on how to respond to skin contamination events.

Please contact your licensing officer if you have any questions regarding your regulatory requirements for event response and event reporting.


PHASE 1 - MEASURING THE CONTAMINATION
Measure & record NET count rate (counts per minute - CPM) and time
Is NET CPM above zero?
No need for immediate decontamination
Decontaminate
Measure and record NET CPM and time
Repeat decontamination
Measure & record NET CPM & time. Is the CPM still decreasing?
Is the individual a NEW?
Were the initial NET CPM and final NET CPM below 10,000 and 500 respectively and recorded within 1 hour of each other?
No requirement to explicitly calculate skin dose. Worst case is below 50 mSv.
Skin dose must be calculated.
To apply the screening levels in Phase 1, the occurrence and timing of the skin contamination event must be known, with the initial measurement made immediately following the event, and subsequent measurements made immediately following decontamination attempts.
If the timing of the skin contamination event is not known, or if a significant amount of time has elapsed between the contamination event and the first measurement (more than 30 minutes), a conservative assumption with respect to the time of the event must be made and the skin dose must be calculated using the method described in Phase 2, based on the count rates measured in Phase 1. To establish the value T (hours) associated with the first measurement, add the elapsed time between the first and second measurement with the estimated elapsed time (hours) between the contamination event and the first measurement.

Background: *the average count rate measured by the instrument used to quantify the contamination as measured in a low dose rate area where nuclear substances are not used or stored.*

NET CPM: *the average count rate, in counts per minute, measured directly over the affected skin (as close as possible without touching), minus the background count rate, ideally measured in a low dose rate area.*

A: *Affected skin surface area (cm^2) or probe active surface area if skin is evenly contaminated over a larger area than the probe. If A is unknown, assume a conservative 1 cm^2.*

E: *Instrument efficiency (e.g., Tc-99m with GM pancake – 0.008)*

DCF: *Dose conversion factor (µSv/h per Bq/cm^2 e.g., 0.25 for Tc-99m)*

T1/2: *Half-life (hours e.g., 6.02 for Tc-99m)*

T: *Time (hours) elapsed between current measurement and <u>subsequent</u> measurement*

PHASE 2 - CALCULATING THE SKIN DOSE

Determine Bq/cm^2 for each measurement:

$$\frac{Bq}{cm^2} = \frac{NET\ CPM}{60 \times A \times E}$$

Determine dose (µSv) for each measurement and time interval:

Bq [0.69

Was the final NET CPM

Determine dose (µSv) for the last time interval to infinity:

Bq

Sum the doses for all measurements & intervals.

PHASE 3 - REPORTING TO THE CNSC

Was the individual a NEW?

Was the calculated dose above 5 mSv?

No requirement to report to the CNSC.

Document, record and investigate every skin contamination event to ensure work practices are optimized and to minimize the probability of repeat

Was the calculated dose above 50 mSv?

Report **<u>immediately</u>** to the CNSC.

For a NEW with a file in the NDR, include a dose change request.

Flow diagram assumptions

1. Any measurement of contamination on the skin should be immediately washed.
2. The skin dose **must** be calculated whenever the incident involves a non-NEW.
3. The calculated skin dose threshold above which immediate reporting to the CNSC is required is **50 mSv** for a NEW and **5 mSv** for a non-NEW.
4. The worst case skin dose resulting from a 10,000 CPM NET measurement followed by a 500 CPM NET measurement after decontamination within one hour is approximately 48.3 mSv (Ga-67 measured with a pancake meter over 1 cm^2, skin decontamination unsuccessful beyond the 500 CPM, and a 27-day exposure). Consequently, the default screening level(s) for which the ascertaining of dose for a NEW is not required is:
    - **Less than 10 000 CPM NET (167 CPS)** on the initial measurement **AND** **500 CPM NET (8.3 CPS)** on the subsequent measurement after decontamination efforts when both measurements are taken **within one hour** of each other

      OR
    - **Less than 500 CPM NET (8.3 CPS)** if only one measurement is taken
5. These default values were established based on a worst case combination of isotope and detector. Note that, as illustrated in appendix 2, at these count rates, the dose incurred from isotopes other than Ga-67 would be much less than 50 mSv.
6. Licensees may choose to establish their own screening thresholds for reporting based on the isotopes they use and detection efficiency of their contamination monitors for those isotopes. In general, this would be expected to increase the count rates, at which reporting is required. Licensees who wish to adopt this approach must submit their evaluation of the screening levels to the CNSC for review prior to implementation.

Note: *Equivalent skin doses that have been ascertained to be above* ***50 mSv*** *should result in the licensee submitting a dose change request to the CNSC on behalf of the affected individual to facilitate the addition of the equivalent dose to the skin to their dose of record in the National Dose Registry.*

Appendix 2 – Skin dose calculations

Skin dose conversion coefficients (μSv/h per Bq/cm^2):

C-14	F-18	P-32	Ga-67	Y-90	Tc-99m	In-111	I-123	I-125	I-131	Tl-201
0.32	1.9	1.9	0.35	2.0	0.25	0.38	0.38	0.021	1.6	0.27

Reference: IAEA-TECDOC-1162

10 000 CPM NET - Doses after 1 hour				
Tc-99m	**Ga-67**	**I-131**	**F-18**	**P-32**
4.9 mSv	7.3 mSv	1.8 mSv	1.3 mSv	1.3 mSv
500 CPM NET - Doses after 27 days				
Tc-99m	**Ga-67**	**I-131**	**F-18**	**P-32**
2.3 mSv	41.0 mSv	22.3 mSv	0.2 mSv	22.8 mSv
Total Doses				
Tc-99m	**Ga-67**	**I-131**	**F-18**	**P-32**
7.2 mSv	48.3 mSv	24.1 mSv	1.5 mSv	24.1 mSv

Assumptions used in skin dose calculations

- Instrument used: pancake (Background 50 CPM)
- Measurement efficiencies: Tc-99m 0.8%, Ga-67 0.8%, I-131 15%, F-18 20%, P-32 25%
- Contaminated skin surface area: 1 cm^2

Low Energy beta-emitters

Low energy beta radiation is blocked readily by the skin or by plastic film or paper. Thus it poses no radiation hazard unless it is ingested and enters body cells where it can exert its effects at very short distances. Dosimeter badges are not needed or required. It is important to take precautions to prevent ingestion or inhalation. Good work habits and frequent wipe checks for surface contamination are essential. Specific problems with individual radioisotopes include:

Tritium - Radiolytic breakdown of labelled compounds is common. The consequent release of either tritium gas or tritiated water vapour can pose a hazard in poorly ventilated areas. Tritiated borohydride is quite unstable and must always be opened and handled inside a fume hood.

Carbon-14 - Most compounds are quite stable and need only to be protected from bacterial breakdown. The common exceptions are bicarbonate and carbonate compounds. These compounds must be stored in a well ventilated area and must always be opened and handled inside a fume hood.

Sulphur-35 - All compounds in common use are stable and need only be protected from bacterial breakdown. Waste should be stored in a well ventilated area and discarded immediately if there is any smell of hydrogen sulphide. When labelling cells in culture with ^{35}S-methionine, (a relatively common biochemical technique), ^{35}S contaminated gases are often produced. Therefore, the culture should be placed in a plastic bag with activated charcoal and the incubator monitored for contamination.

Calcium-45 - All compounds in common use are very stable. Cleaning of contaminated surfaces is difficult and is best accomplished with mild acid (acetic) and chelators.

High Energy Beta-emitters (eg Phosphorous-32, Chlorine-36)

High energy beta radiation (high velocity electrons) penetrates skin readily. Whole body dosimeter badges must be worn. As well, the high velocity electrons displace orbital electrons from molecules and cause the emission of low-energy X-rays called bremsstrahlung. This displacement effect is more efficient in dense materials. Thus it is necessary to shield high energy beta radiation with low density shielding. About 1 cm of plastic or wood is effective shielding for either Phosphorus-32 or Chlorine-36. Substantial irradiation of the hands can occur when these radioisotopes are handled. It is mandatory to wear finger badges if more than 1.35 mCi of Phosphorus-32 is handled and finger badges are recommended if amounts of more than 135 μCi are handled. Good work habits are essential to prevent accidental ingestion. Contamination checks are most conveniently done with a standard survey meter with a common Geiger-Muller detector.

Appendix 3 - Measurement Units Conversion Table

Système International (SI) Units * 1 Bq = 1 disintegration/second

The curie (Ci) is replaced by the becquerel (Bq)*

1	kilocurie (kCi)	=	37	terabecquerels (TBq)
1	curie (Ci)	=	37	gigabecquerels (GBq)
1	millicurie (mCi)	=	37	megabecquerels (MBq)
1	microcurie (µCi)	=	37	kilobecquerels (kBq)
1	nanocurie (nCi)	=	37	becquerels (Bq)

The becquerel (Bq)* replaces the curie (Ci)

1	terabecquerel (TBq)	=	27	curies (Ci)
1	gigabecquerel (GBq)	=	27	millicuries (mCi)
1	megabecquerel (MBq)	=	27	microcuries (µCi)
1	kilobecquerel (kBq)	=	27	nanocuries (nCi)
1	becquerel (Bq)	=	27	picocuries (pCi)

The rem (rem) is replaced by the sievert (Sv)

1	kilorem (krem)	=	10	sieverts (Sv)
1	rem (rem)	=	10	millisieverts (mSv)
1	millirem (mrem)	=	10	microsieverts (µSv)
1	microrem (µrem)	=	10	nanosieverts (nSv)

The sievert (Sv) replaces the rem (rem)

1	sievert (Sv)	=	100	rems (rem)
1	millisievert (mSv)	=	100	millirems (mrem)
1	microsievert (µSv)	=	100	microrems (µrem)
1	nanosievert (nSv)	=	100	nanorems (nrem)

The rad (rad) is replaced by the gray (Gy)

1	kilorad (krad)	=	10	grays (Gy)
1	rad (rad)	=	10	milligrays (mGy)
1	millirad (mrad)	=	10	micrograys (µGy)
1	microrad (µrad)	=	10	nanograys (Gy)

The gray (Gy) replaces the rad (rad)

1	gray (Gy)	=	100	rads (rad)
1	milligray (mGy)	=	100	millirads (mrad)
1	microgray (µGy)	=	100	microrads (µrad)
1	nanogray (Gy)	=	100	nanorads (nrad)

Online Radiation Calculator (Rad Pro Calculator) - http://www.radprocalculator.com/

Source: Nuclear Substances and Radiation Devices Regulations (2015), SCHEDULE 1

(Section 1 and paragraph 38(1)(e))

EXEMPTION QUANTITIES

Column 1 Radioactive Nuclear Substance	Column 2 Activity Concentration (Bq/g)	Column 3 Activity (Bq)
Actinium 227	1×10^{-1}	1×10^{3}
Actinium 228	1×10^{1}	1×10^{6}
Americium 241	1×10^{0}	1×10^{4}
Americium 242	1×10^{3}	1×10^{6}
Americium 242m[a]	1×10^{0}	1×10^{4}
Americium 243[a]	1×10^{0}	1×10^{3}
Antimony 122	1×10^{2}	1×10^{4}
Antimony 124	1×10^{1}	1×10^{6}
Antimony 125	1×10^{2}	1×10^{6}
Argon 37	1×10^{6}	1×10^{8}
Argon 41	1×10^{2}	1×10^{9}
Arsenic 73	1×10^{3}	1×10^{7}
Arsenic 74	1×10^{1}	1×10^{6}
Arsenic 76	1×10^{2}	1×10^{5}
Arsenic 77	1×10^{3}	1×10^{6}
Astatine 211	1×10^{3}	1×10^{7}
Barium 131	1×10^{2}	1×10^{6}
Barium 133	1×10^{2}	1×10^{6}
Barium 140[a]	1×10^{1}	1×10^{5}
Berkelium 249	1×10^{3}	1×10^{6}
Beryllium 7	1×10^{3}	1×10^{7}
Bismuth 206	1×10^{1}	1×10^{5}
Bismuth 207	1×10^{1}	1×10^{6}
Bismuth 210	1×10^{3}	1×10^{6}
Bismuth 212[a]	1×10^{1}	1×10^{5}
Bromine 82	1×10^{1}	1×10^{6}
Cadmium 107	1×10^{3}	1×10^{7}
Cadmium 109	1×10^{4}	1×10^{6}
Cadmium 113m	1×10^{3}	1×10^{6}
Cadmium 115	1×10^{2}	1×10^{6}
Cadmium 115m	1×10^{3}	1×10^{6}
Calcium 45	1×10^{4}	1×10^{7}
Calcium 47	1×10^{1}	1×10^{6}
Californium 246	1×10^{3}	1×10^{6}
Californium 248	1×10^{1}	1×10^{4}
Californium 249	1×10^{0}	1×10^{3}

Californium 250	1×10^{1}	1×10^{4}
Californium 251	1×10^{0}	1×10^{3}

Column 1 Radioactive Nuclear Substance	Column 2 Activity Concentration (Bq/g)	Column 3 Activity (Bq)
Californium 252	1×10^{1}	1×10^{4}
Californium 253	1×10^{2}	1×10^{5}
Californium 254	1×10^{0}	1×10^{3}
Carbon 11	1×10^{1}	1×10^{6}
Carbon 14	1×10^{4}	1×10^{7}
Cerium 139	1×10^{2}	1×10^{6}
Cerium 141	1×10^{2}	1×10^{7}
Cerium 143	1×10^{2}	1×10^{6}
Cerium 144[a]	1×10^{2}	1×10^{5}
Cesium 129	1×10^{2}	1×10^{5}
Cesium 131	1×10^{3}	1×10^{6}
Cesium 132	1×10^{1}	1×10^{5}
Cesium 134	1×10^{1}	1×10^{4}
Cesium 134m	1×10^{3}	1×10^{5}
Cesium 135	1×10^{4}	1×10^{7}
Cesium 136	1×10^{1}	1×10^{5}
Cesium 137[a]	1×10^{1}	1×10^{4}
Cesium 138	1×10^{1}	1×10^{4}
Chlorine 36	1×10^{4}	1×10^{6}
Chlorine 38	1×10^{1}	1×10^{5}
Chromium 49	1×10^{1}	1×10^{6}
Chromium 51	1×10^{3}	1×10^{7}
Cobalt 55	1×10^{1}	1×10^{6}
Cobalt 56	1×10^{1}	1×10^{5}
Cobalt 57	1×10^{2}	1×10^{6}
Cobalt 58	1×10^{1}	1×10^{6}
Cobalt 58m	1×10^{4}	1×10^{7}
Cobalt 60	1×10^{1}	1×10^{5}
Cobalt 60m	1×10^{3}	1×10^{6}
Cobalt 61	1×10^{2}	1×10^{6}
Cobalt 62m	1×10^{1}	1×10^{5}
Copper 60	1×10^{1}	1×10^{5}
Copper 64	1×10^{2}	1×10^{6}
Copper 67	1×10^{2}	1×10^{6}
Curium 242	1×10^{2}	1×10^{5}
Curium 243	1×10^{0}	1×10^{4}
Curium 244	1×10^{1}	1×10^{4}
Curium 245	1×10^{0}	1×10^{3}
Curium 246	1×10^{0}	1×10^{3}
Curium 247	1×10^{0}	1×10^{4}

Curium 248	1×10^0	1×10^3

Column 1 Radioactive Nuclear Substance	Column 2 Activitv Concentration (Bq/g)	Column 3 Activitv (Bq)
Dysprosium 159	1×10^3	1×10^7
Dysprosium 165	1×10^3	1×10^6
Dysprosium 166	1×10^3	1×10^6
Einsteinium 253	1×10^2	1×10^5
Einsteinium 254	1×10^1	1×10^4
Einsteinium 254m	1×10^2	1×10^6
Erbium 169	1×10^4	1×10^7
Erbium 171	1×10^2	1×10^6
Europium 152	1×10^1	1×10^6
Europium 152m	1×10^2	1×10^6
Europium 154	1×10^1	1×10^6
Europium 155	1×10^2	1×10^7
Fermium 254	1×10^4	1×10^7
Fermium 255	1×10^3	1×10^6
Fluorine 18	1×10^1	1×10^6
Gadolinium 153	1×10^2	1×10^7
Gadolinium 159	1×10^3	1×10^6
Gallium 67	1×10^2	1×10^6
Gallium 72	1×10^1	1×10^5
Germanium 68	1×10^1	1×10^5
Germanium 71	1×10^4	1×10^8
Gold 195	1×10^2	1×10^7
Gold 198	1×10^2	1×10^6
Gold 199	1×10^2	1×10^6
Hafnium 181	1×10^1	1×10^6
Holmium 166	1×10^3	1×10^5
Hydrogen 3	1×10^6	1×10^9
Indium 111	1×10^2	1×10^6
Indium 113m	1×10^2	1×10^6
Indium 114m	1×10^2	1×10^6
Indium 115	1×10^3	1×10^5
Indium 115m	1×10^2	1×10^6
Iodine 123	1×10^2	1×10^7
Iodine 125	1×10^3	1×10^6
Iodine 126	1×10^2	1×10^6
Iodine 129	1×10^2	1×10^5
Iodine 130	1×10^1	1×10^6
Iodine 131	1×10^2	1×10^6
Iodine 132	1×10^1	1×10^5
Iodine 133	1×10^1	1×10^6
Iodine 134	1×10^1	1×10^5

Column 1 Radioactive Nuclear Substance	Column 2 Activity Concentration (Bq/g)	Column 3 Activity (Bq)
Iodine 135	1×10^{1}	1×10^{6}
Iridium 190	1×10^{1}	1×10^{6}
Iridium 192	1×10^{1}	1×10^{4}
Iridium 194	1×10^{2}	1×10^{5}
Iron 52	1×10^{1}	1×10^{6}
Iron 55	1×10^{4}	1×10^{6}
Iron 59	1×10^{1}	1×10^{6}
Krypton 74	1×10^{2}	1×10^{9}
Krypton 76	1×10^{2}	1×10^{9}
Krypton 77	1×10^{2}	1×10^{9}
Krypton 79	1×10^{3}	1×10^{5}
Krypton 81	1×10^{4}	1×10^{7}
Krypton 83m	1×10^{5}	1×10^{12}
Krypton 85	1×10^{5}	1×10^{4}
Krypton 85m	1×10^{3}	1×10^{10}
Krypton 87	1×10^{2}	1×10^{9}
Krypton 88	1×10^{2}	1×10^{9}
Lanthanum 140	1×10^{1}	1×10^{5}
Lead 203	1×10^{2}	1×10^{6}
Lead 210[a]	1×10^{1}	1×10^{4}
Lead 212[a]	1×10^{1}	1×10^{5}
Lutetium 177	1×10^{3}	1×10^{7}
Manganese 51	1×10^{1}	1×10^{5}
Manganese 52	1×10^{1}	1×10^{5}
Manganese 52m	1×10^{1}	1×10^{5}
Manganese 53	1×10^{4}	1×10^{9}
Manganese 54	1×10^{1}	1×10^{6}
Manganese 56	1×10^{1}	1×10^{5}
Mercury 197	1×10^{2}	1×10^{7}
Mercury 197m	1×10^{2}	1×10^{6}
Mercury 203	1×10^{2}	1×10^{5}
Molybdenum 90	1×10^{1}	1×10^{6}
Molybdenum 93	1×10^{3}	1×10^{8}
Molybdenum 99	1×10^{2}	1×10^{6}
Molybdenum 101	1×10^{1}	1×10^{6}
Neodymium 147	1×10^{2}	1×10^{6}
Neodymium 149	1×10^{2}	1×10^{6}
Neptunium 237[a]	1×10^{0}	1×10^{3}
Neptunium 239	1×10^{2}	1×10^{7}
Neptunium 240	1×10^{1}	1×10^{6}
Nickel 59	1×10^{4}	1×10^{8}

Column 1 Radioactive Nuclear Substance	Column 2 Activity Concentration (Bq/g)	Column 3 Activity (Bq)
Nickel 63	1×10^5	1×10^8
Nickel 65	1×10^1	1×10^6
Niobium 93m	1×10^4	1×10^7
Niobium 94	1×10^1	1×10^6
Niobium 95	1×10^1	1×10^6
Niobium 97	1×10^1	1×10^6
Niobium 98	1×10^1	1×10^5
Nitrogen 13	1×10^2	1×10^9
Osmium 185	1×10^1	1×10^6
Osmium 191	1×10^2	1×10^7
Osmium 191m	1×10^3	1×10^7
Osmium 193	1×10^2	1×10^6
Oxygen 15	1×10^2	1×10^9
Palladium 103	1×10^3	1×10^8
Palladium 109	1×10^3	1×10^6
Phosphorous 32	1×10^3	1×10^5
Phosphorous 33	1×10^5	1×10^8
Platinum 191	1×10^2	1×10^6
Platinum 193m	1×10^3	1×10^7
Platinum 197	1×10^3	1×10^6
Platinum 197m	1×10^2	1×10^6
Plutonium 234	1×10^2	1×10^7
Plutonium 235	1×10^2	1×10^7
Plutonium 236	1×10^1	1×10^4
Plutonium 237	1×10^3	1×10^7
Plutonium 238	1×10^0	1×10^4
Plutonium 239	1×10^0	1×10^4
Plutonium 240	1×10^0	1×10^3
Plutonium 241	1×10^2	1×10^5
Plutonium 242	1×10^0	1×10^4
Plutonium 243	1×10^3	1×10^7
Plutonium 244	1×10^0	1×10^4
Polonium 203	1×10^1	1×10^6
Polonium 205	1×10^1	1×10^6
Polonium 207	1×10^1	1×10^6
Polonium 210	1×10^1	1×10^4
Potassium 40	1×10^2	1×10^6
Potassium 42	1×10^2	1×10^6
Potassium 43	1×10^1	1×10^6
Praseodymium 142	1×10^2	1×10^5
Praseodymium 143	1×10^4	1×10^6

Column 1 Radioactive Nuclear Substance	Column 2 Activity Concentration (Bq/g)	Column 3 Activity (Bq)
Promethium 147	1×10^4	1×10^7
Promethium 149	1×10^3	1×10^6
Protactinium 230	1×10^1	1×10^6
Protactinium 231	1×10^0	1×10^3
Protactinium 233	1×10^2	1×10^7
Radium 223[a]	1×10^2	1×10^5
Radium 224[a]	1×10^1	1×10^5
Radium 225	1×10^2	1×10^5
Radium 226[a]	1×10^1	1×10^4
Radium 227	1×10^2	1×10^6
Radium 228[a]	1×10^1	1×10^5
Radon 220[a]	1×10^4	1×10^7
Radon 222[a]	1×10^1	1×10^8
Rhenium 186	1×10^3	1×10^6
Rhenium 187	1×10^6	1×10^9
Rhenium 188	1×10^2	1×10^5
Rhodium 103m	1×10^4	1×10^8
Rhodium 105	1×10^2	1×10^7
Rubidium 86	1×10^2	1×10^5
Ruthenium 97	1×10^2	1×10^7
Ruthenium 103	1×10^2	1×10^6
Ruthenium 105	1×10^1	1×10^6
Ruthenium 106[a]	1×10^2	1×10^5
Samarium 151	1×10^4	1×10^8
Samarium 153	1×10^2	1×10^6
Scandium 46	1×10^1	1×10^6
Scandium 47	1×10^2	1×10^6
Scandium 48	1×10^1	1×10^5
Selenium 75	1×10^2	1×10^6
Selenium 79	1×10^4	1×10^7
Silicon 31	1×10^3	1×10^6
Silver 105	1×10^2	1×10^6
Silver 110m	1×10^1	1×10^6
Silver 111	1×10^3	1×10^6
Sodium 22	1×10^1	1×10^6
Sodium 24	1×10^1	1×10^5
Strontium 85	1×10^2	1×10^6
Strontium 85m	1×10^2	1×10^7
Strontium 87m	1×10^2	1×10^6
Strontium 89	1×10^3	1×10^6
Strontium 90[a]	1×10^2	1×10^4

Column 1 Radioactive Nuclear Substance	Column 2 Activity Concentration (Bq/g)	Column 3 Activity (Bq)
Strontium 91	1×10^1	1×10^5
Strontium 92	1×10^1	1×10^6
Sulphur 35	1×10^5	1×10^8
Tantalum 182	1×10^1	1×10^4
Technetium 96	1×10^1	1×10^6
Technetium 96m	1×10^3	1×10^7
Technetium 97	1×10^3	1×10^8
Technetium 97m	1×10^3	1×10^7
Technetium 99	1×10^4	1×10^7
Technetium 99m	1×10^2	1×10^7
Tellurium 123m	1×10^2	1×10^7
Tellurium 125m	1×10^3	1×10^7
Tellurium 127	1×10^3	1×10^6
Tellurium 127m	1×10^3	1×10^7
Tellurium 129	1×10^2	1×10^6
Tellurium 129m	1×10^3	1×10^6
Tellurium 131	1×10^2	1×10^5
Tellurium 131m	1×10^1	1×10^6
Tellurium 132	1×10^2	1×10^7
Tellurium 133	1×10^1	1×10^5
Tellurium 133m	1×10^1	1×10^5
Tellurium 134	1×10^1	1×10^6
Terbium 160	1×10^1	1×10^6
Thallium 200	1×10^1	1×10^6
Thallium 201	1×10^2	1×10^6
Thallium 202	1×10^2	1×10^6
Thallium 204	1×10^4	1×10^4
Thorium 226[a]	1×10^3	1×10^7
Thorium 227	1×10^1	1×10^4
Thorium 228[a]	1×10^0	1×10^4
Thorium 229[a]	1×10^0	1×10^3
Thorium 230	1×10^0	1×10^4
Thorium 231	1×10^3	1×10^7
Thorium 232	1×10^1	1×10^4
Thorium 234[a]	1×10^3	1×10^5
Thorium natural[a]	1×10^0	1×10^3
Thulium 170	1×10^3	1×10^6
Thulium 171	1×10^4	1×10^8
Tin 113	1×10^3	1×10^7
Tin 125	1×10^2	1×10^5
Tungsten 181	1×10^3	1×10^7

Column 1 Radioactive Nuclear Substance	Column 2 Activity Concentration (Bq/g)	Column 3 Activity (Bq)
Tungsten 185	1×10^{4}	1×10^{7}
Tungsten 187	1×10^{2}	1×10^{6}
Uranium 230[a]	1×10^{1}	1×10^{5}
Uranium 231	1×10^{2}	1×10^{7}
Uranium 232[a]	1×10^{0}	1×10^{3}
Uranium 233	1×10^{1}	1×10^{4}
Uranium 234	1×10^{1}	1×10^{4}
Uranium 235[a]	1×10^{1}	1×10^{4}
Uranium 236	1×10^{1}	1×10^{4}
Uranium 237	1×10^{2}	1×10^{6}
Uranium 238[a]	1×10^{1}	1×10^{4}
Uranium 239	1×10^{2}	1×10^{6}
Uranium 240	1×10^{3}	1×10^{7}
Uranium 240[a]	1×10^{1}	1×10^{6}
Uranium natural[a]	1×10^{0}	1×10^{3}
Vanadium 48	1×10^{1}	1×10^{5}
Xenon 123	1×10^{2}	1×10^{9}
Xenon 129m	1×10^{3}	1×10^{4}
Xenon 131m	1×10^{4}	1×10^{4}
Xenon 133	1×10^{3}	1×10^{4}
Xenon 135	1×10^{3}	1×10^{10}
Ytterbium 169	1×10^{2}	1×10^{7}
Ytterbium 175	1×10^{3}	1×10^{7}
Yttrium 90	1×10^{3}	1×10^{5}
Yttrium 91	1×10^{3}	1×10^{6}
Yttrium 91m	1×10^{2}	1×10^{6}
Yttrium 92	1×10^{2}	1×10^{5}
Yttrium 93	1×10^{2}	1×10^{5}
Zinc 65	1×10^{1}	1×10^{6}
Zinc 69	1×10^{4}	1×10^{6}
Zinc 69m	1×10^{2}	1×10^{6}
Zirconium 93[a]	1×10^{3}	1×10^{7}
Zirconium 95	1×10^{1}	1×10^{6}
Zirconium 97[a]	1×10^{1}	1×10^{5}

[a] Parent nuclides and their progeny included in secular equilibri- um are listed in the following:

Am-242m Am-

242 Am-243 N

p-239 Ba-

140 La-140

Bi-212 Tl-208 (0.36), Po-212

(0.64) Ce-144 Pr-144

Cs-137 Ba-137m

Np-237 Pa-233
Pb-210 Bi-210, Po-210
Pb-212 Bi-212, Tl-208 (0.36), Po-212 (0.64)
Ra-223 Rn-219, Po-215, Pb-211, Bi-211, Tl-207

Ra-224 Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64) Ra-226 Rn-

222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210,
Po-210 Ra-228 Ac-

228 Rn-220 Po-216

Rn-222 Po-218, Pb-214, Bi-214, Po-214 Ru-106 Rh-

106

Sr-90 Y-90
Th-226 Ra-222, Rn-218, Po-214

Th-228 Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)

Th-229 Ra-225, Ac-225, Fr-221, At-217, Bi-213, Po-213, Pb-209 Th-

234 Pa-234m

Th-nat Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)

U-230 Th-226, Ra-222, Rn-218, Po-214

U-232 Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)

U-235 Th-231
U-238 Th-234, Pa-234m U-240

Np-240m

U-nat Th-234, Pa-234m, U-234, Th-230, Ra-226, Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210, Po-210

Zr-93 Nb-93m Zr-97

Nb-97

SOR/2008-119, s. 38.

Exemption Quantity means any of the following:

(a) in respect of a radioactive nuclear substance set out in column 1 of Schedule 1,
- (i) if the radioactive nuclear substance is uniformly distributed in material and not in bulk quantity, the corresponding activity concentration set out in column 2, or
- (ii) the corresponding activity set out in column 3;

(b) in respect of a radioactive nuclear substance that is not set out in column 1 of Schedule 1,
- (i) if the atomic number of the substance is equal to or less than 81,
  - (A) 10 Bq/g if the radioactive nuclear substance is uniformly distributed in material and not in bulk quantity, or
  - (B) 10,000 Bq,
- (ii) if the atomic number of the substance is greater than 81 and the substance, or its short-lived radioactive progeny, does not emit alpha radiation,

(A) 10 Bq/g if the radioactive nuclear substance is uniformly distributed in material and not in bulk quantity, or

(B) 10,000 Bq, or

(iii) if the atomic number of the substance is greater than 81 and the substance, or its short-lived radioactive progeny, emits alpha radiation,

(A) 1 Bq/g if the radioactive nuclear substance is uniformly distributed in material and not in bulk quantity, or

(B) 1,000 Bq; or

(c) in respect of more than one radioactive nuclear substance,

(i) if the radioactive nuclear substances are uniformly distributed in material and not in bulk quantity, the quotient obtained by dividing the total activity concentration by the sum of quotients obtained by dividing the activity concentration of each radioactive nuclear substance by its corresponding exemption quantity as referred to in paragraph (a) or (b), or

(ii) the quotient obtained by dividing the total activity by the corresponding sum of quotients obtained by dividing the activity of each radioactive nuclear substance by its corresponding exemption quantity as referred to in paragraph (a) or (b).

Nuclear Substance	DCF (Sv/Bq) Inhalation	ALI (Bq) Inhalation	DCF (Sv/Bq) Ingestion	ALI (Bq) Ingestion
Rhenium 188 (^{188}Re)	7.4×10^{-10}	2.7×10^{07}	1.4×10^{-09}	1.4×10^{07}
Rubidium 86 (^{86}Rb)	1.3×10^{-09}	1.5×10^{07}	2.8×10^{-09}	7.1×10^{06}
Ruthenium 103 (^{103}Ru)	2.2×10^{-09}	9.1×10^{06}	7.3×10^{-10}	2.7×10^{07}
Scandium 46 (^{46}Sc)	4.8×10^{-09}	4.2×10^{06}	1.5×10^{-09}	1.3×10^{07}
Selenium 75 (^{75}Se)	1.7×10^{-09}	1.2×10^{07}	2.6×10^{-09}	7.7×10^{06}
Silicon 31 (^{31}Si)	1.1×10^{-10}	1.8×10^{08}	1.6×10^{-10}	1.3×10^{08}
Silicon 32 (^{32}Si)	5.5×10^{-08}	3.6×10^{05}	5.6×10^{-10}	3.5×10^{07}
Silver 110m (^{110m}Ag)	7.3×10^{-09}	2.7×10^{06}	2.8×10^{-09}	7.1×10^{06}
Sodium 22 (^{22}Na)	2.0×10^{-09}	1.0×10^{07}	3.2×10^{-09}	6.3×10^{06}
Sodium 24 (^{24}Na)	5.3×10^{-10}	3.8×10^{07}	4.3×10^{-10}	4.7×10^{07}
Strontium 85 (^{85}Sr)	6.4×10^{-10}	3.1×10^{07}	5.6×10^{-10}	3.6×10^{07}
Strontium 89 (^{89}Sr)	5.6×10^{-09}	3.6×10^{06}	2.6×10^{-09}	7.7×10^{06}
Strontium 90 (^{90}Sr)	7.7×10^{-08}	2.6×10^{05}	2.8×10^{-08}	7.1×10^{05}
Sulphur 35 (inorganic) (^{35}S)	1.1×10^{-09}	1.8×10^{07}	1.9×10^{-10}	1.1×10^{08}
Sulphur 35 (organic v) (^{35}S)	1.2×10^{-10}	1.7×10^{08}	7.7×10^{-10}	2.6×10^{07}
Technetium 99m (^{99m}Tc)	2.9×10^{-11}	6.9×10^{08}	2.2×10^{-11}	9.1×10^{08}
Technetium 99 (^{99}Tc)	3.2×10^{-09}	6.3×10^{06}	7.8×10^{-10}	2.6×10^{07}
Thallium 201 (^{201}Tl)	7.6×10^{-11}	2.6×10^{08}	9.5×10^{-11}	2.1×10^{08}
Thallium 204 (^{204}Tl)	6.2×10^{-10}	3.2×10^{07}	1.3×10^{-09}	1.5×10^{07}
Thorium 228 (^{228}Th)	3.2×10^{-05}	6.3×10^{02}	6.9×10^{-08}	2.9×10^{05}
Thorium 229 (^{229}Th)	6.9×10^{-05}	2.9×10^{02}	4.8×10^{-07}	4.2×10^{04}
Thorium 230 (^{230}Th)	2.8×10^{-05}	7.1×10^{02}	2.1×10^{-07}	9.5×10^{04}
Tin 113 (^{113}Sn)	1.9×10^{-09}	1.1×10^{07}	7.3×10^{-10}	2.7×10^{07}
Uranium (natural) ††	6.3×10^{-06}	3.2×10^{03}	9.5×10^{-09}	2.1×10^{06}
Uranium (depleted) ††	5.9×10^{-06}	3.4×10^{03}	1.1×10^{-08}	1.9×10^{06}
Uranium 232 (^{232}U) ††	2.6×10^{-05}	7.7×10^{02}	3.3×10^{-07}	6.1×10^{04}
Uranium 233 (^{233}U) ††	6.9×10^{-06}	2.9×10^{03}	5.0×10^{-08}	4.0×10^{05}
Uranium 235 (^{235}U) ††	6.1×10^{-06}	3.3×10^{03}	4.6×10^{-08}	4.3×10^{05}
Uranium 236 (^{236}U) ††	6.3×10^{-06}	3.2×10^{03}	4.6×10^{-08}	4.3×10^{05}
Uranium 238 (^{238}U) ††	5.7×10^{-06}	3.5×10^{03}	4.4×10^{-08}	4.5×10^{05}
Xenon 133 (gas) Bq/cm^3 ‡ (^{133}Xe)	1.2×10^{-10}	6.7×10^{05}	---	---
Xenon 135 (gas) Bq/cm^3 ‡ (^{135}Xe)	9.6×10^{-10}	8.3×10^{04}	---	---
Yttrium 87 (^{87}Y)	5.3×10^{-10}	3.8×10^{07}	5.5×10^{-10}	3.6×10^{07}
Yttrium 90 (^{90}Y)	1.7×10^{-09}	1.2×10^{07}	2.7×10^{-09}	7.4×10^{06}
Zinc 65 (^{65}Zn)	2.8×10^{-09}	7.1×10^{06}	3.9×10^{-09}	5.1×10^{06}

* CO_2 value from ICRP-based data published from 1955-1970. New data (1990-2000) and revision of the model (2004) recommend higher dose coefficient. Revised $^{14}CO_2$ dose coefficient from Leggett, R.W., Radiation Protection Dosimetry Vol. 208, pp. 203-213 (2004).

** Hydrogenated Tritium Oxide (HTO), also referred to as "tritiated water"
ICRP DCF is 1.8E-11; value used here is from Health Canada 83-EHD-87 (1983) and RSP-182B (2004).

† Organically Bound Tritium (OBT)

‡ The concentration equivalent of 20 mSv per year (assuming 250 working days and 8-hour workday).

†† Type S (slow), insoluble compounds

Annual Limit on Intake (ALI)

The activity, in Becquerels, 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.

Note that the appropriate ALI value is the one that best represents the risks associated with the nuclear substance. If it cannot be determined whether the greater risk is related to inhalation or ingestion of the substance, then the most restrictive value should be used.

DCF

Dose conversion factor; the committed effective dose in Sv, per unit activity in Bq, delivered by a given radionuclide of a given form. It is related to the ALI, in that the ALI can be calculated by dividing the DCF into 0.02 Sv (20 mSv).

Appendix 6 – Radioisotope Information for Specific Radioisotopes

The Canadian Nuclear Safety Commission (CNSC) publishes a *Radionuclide Information Booklet,* the purpose of which is to provide practical information to aid radiation protection specialists at Canadian Nuclear Safety Commission (CNSC) licensed facilities.

This booklet replaces the previously published Radiation Safety Data Sheets.

However, **it is important to ensure the most recent information pages are being used**, and it is ultimately the user's responsibility to use the information appropriately. For this reason, **excerpts from the book are not included in the Queen's University Radiation Safety Manual and instead the user is referred to the CNSC website to consult the most up-to-date version of the book.**

The *Radionuclide Information Booklet* contains information pages for radionuclides commonly used in the medical, research, and industrial sectors. These information pages may be posted at CNSC-licensed facilities as a convenient way to quickly find information.

Be sure to consult the first four pages of the *Radionuclide Information Booklet* that describe each of the six parts of the pages on specific radionuclides.

Radionuclides with long decay chains including multiple short-lived progeny are not included in the *Radionuclide Information Booklet* as their information is too complex to be captured within this format.

Appendix 7 – Classes of Nuclear Substances

The following tables organizes a number of common nuclear substances, including those for which surface contamination and waste disposal limits are typically incorporated into CNSC licences, into three classes - "Class A", "Class B" or "Class C" - on the basis of common radiological characteristics.

For nuclear substances not listed, please contact the Radiation Safety Officer.

CLASS	RADIONUCLIDE				
CLASS A	All alpha emitters and their daughter isotopes			Na-22	Na-24
	Co-60	Ir-192	Sb-124	Ta-182	Zn-65
CLASS B	As-74	Au-198	Br-82	Co-58	F-18
	Fe-59	Ga-67	Gd-153	Hg-203	I-131
	In-111	In-114m	Nb-95	Rb-84	Rb-86
	Sc-46	Se-75	Sm-153	Sn-113	Sn-123
	Sr-85	Sr-90			
CLASS C	Au-195m	C-14	Ca-45	Cd-109	Ce-144
	Cl-36	Co-57	Cr-51	H-3	I-123
	I-125	Ni-63	P-32	P-33	Re-186
	Re-188	Ru-103	S-35	Sr-89	Tc-99
	Tc-99m	Tl-201	Y-90	Yb-169	

The application form is presented below for your information. Please use the fillable form available on the Environmental Health and Safety Website or contact the R$O directly.

New Radioisotope Permit Application

Queen's University Radiation Protection Program

1. **Name:**
2. **Department:**
3. **E-mail address:**
4. **Building:**
5. **Office room number:** **6. Office telephone number:**
7. **Emergency telephone number:**
8. **Laboratory room(s) number(s):**
9. **University position:**
10. **Queen's Personal number:**
11. **Radioisotope work experience:** (In detail)

12. **Open sources required:**

Radioisotope	Open source delivery rate

(Provide max amount to be ordered, frequency of orders and max amount to be on hand at any given time)

13. **Sealed sources required:**

Radioisotope	Activity	Device where it will be used

Revision Date: October 2022

14. Experimental Procedures: ☐ In Vitro ☐ In Vivo **(non-human)**

15. Additional information:

a) Can aerosols or gases be produced? ☐ No ☐ Yes (specify)

b) Are biological material used in the same experiment? ☐ No ☐ Yes (specify)

c) Are dangerous chemicals used in the same experiment? ☐ No ☐ Yes (specify)

I agree to abide by the Canadian Nuclear Safety Act and regulations
http://cnsc-ccsn.gc.ca/eng/acts-and-regulations/regulations/index.cfm
and by the Queen's University Radiation Safety Policies and Procedures Manual 2022.

Applicant's Signature:

Date:

Department Signature:

(Chair/Head of Department)

(Printed name)

Please email completed application to:

jamie.coad@queensu.ca

Revision Date: October 2022

Appendix 9 – Radioisotope Inventory Form

Permit Holder ___________________________ Permit Number ______________

Department ______________________________ Room No. ___________________

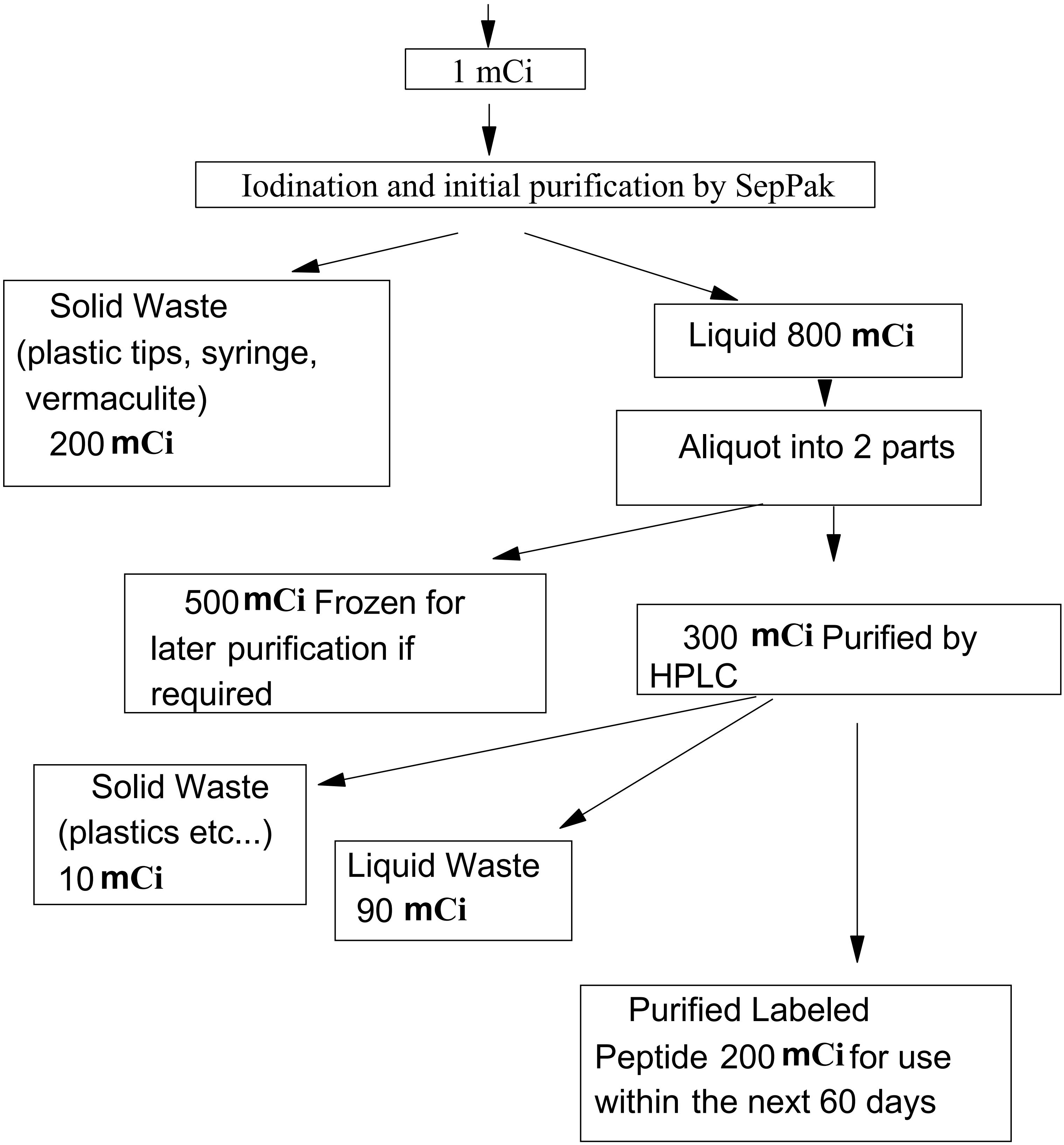
Isotope ________ Purchase Order Number________

Lot Number __________ Amount Purchased ____________

Date dd/mm/yy	Initial of Handler	Amount used (µCi)	Amount Disposed of or Decayed (µCi)	Amount Remaining (µCi)

Please indicate method(s) used for disposal:

Iodination FLOW CHART



In vitro Binding Study

0.05 uCi/Well (100,000 cpm)

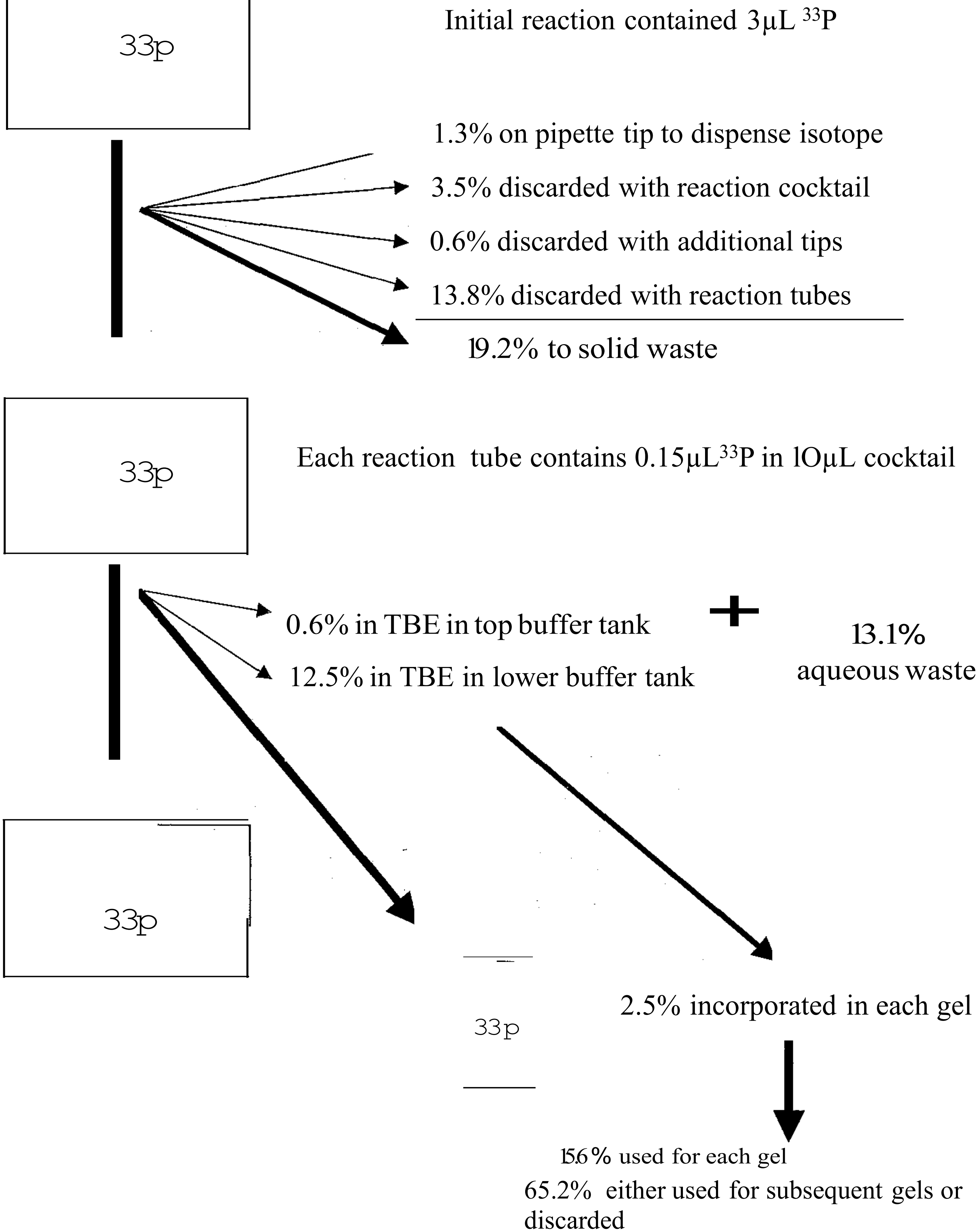
↓

125I -ANP- Receptor Complex (0.005 uCi)
+
0.045 uCi in wash 0.005 uCi in pellet
(wash disposed via liquid waste EH&S)

↓

125I - ANP receptor complex pellet counted in tube.
(Tube disposed via solid radioactive waste, EH&S)

^{33}P Isotope Disposal



DEFACE

- all radioactive warning labels (don't use radioactive warning tape to seal bag).

SEGREGATE

- only one isotope per bag or containment vessel.

SEPARATE

- active material from slightly contaminated material (reduce the bulk of material that needs to be held for long periods to decay)
- liquid-filled scintillation vials from all other material (see 2. below)
- lead pigs from any other wastes - wipe test pigs (keep record) and make arrangements through the Department of Environmental Health and Safety for disposal

LABEL

- fill out tag and attach one per bag (not to be used to seal bag)

You need to identify the isotope and give the activity in microcuries (uCi), give the date, your permit number and name of the person packaging the material.

Tags can be obtained from Environmental Health & Safety

PACKAGING

1. All solid radioactive material, excluding scintillation vials, must be packaged in clear plastic bags as we are required by the Canadian Nuclear Safety Commission to do visual checks to ensure that all radiation warning labels have been defaced.

2. Scintillation vials should be packaged in heavy bags (6 mil) or other bags as approved by the Department of Environmental Health and Safety. Users must ensure that bags are not leaking. Individual vials must be securely sealed and separated from all other materials. Tags should indicate activity and be clearly marked as VIALS.

   Bags are available from Environmental Health & Safety

3. Flammable or organic liquid isotope material must be placed in flammable waste disposal cans as for other flammable wastes. Tags must be attached to indicate isotope(s) and activity. Radioisotopes may be mixed with other materials provided that the materials are compatible. Non-flammable aqueous isotope materials should be treated in the same fashion or placed in other suitable containers provided they are well sealed, do not leak and have been approved by the Department of Environmental Health and Safety

REQUEST PICKUP

Fill out the form on the EH&S website to request a pickup.

SCHEDULING

See the calendar on the EH&S website for scheduling of waste pick up.

Introduction

These instructions and procedures provide general guidance for monitoring radioactive contamination, and relating the monitoring results to the CNSC radioisotope licence criteria.

Each CNSC radioisotope licence authorizing the use of open source radioactive material contains a condition which states the regulatory criteria pertaining to radioactive contamination. Our licence condition is as follows:

> Contamination Criteria:
> The licensee shall ensure that for nuclear substances listed in the licence application guide table titled "Classifications of Radionuclides";
> (a) non-fixed contamination in all areas, rooms or enclosures where unsealed nuclear substances are used or stored does not exceed:
> (i) 3 bequerels per square centimetre of for all Class A radionuclides;
> (ii) 30 bequerels per square centimetre of for all Class B radionuclides; or
> (iii) 300 bequerels per square centimetre of for all Class C radionuclides;
> averaged over an area not exceeding 100 square centimetres; and
> (b) non-fixed contamination in all other areas does not exceed:
> (i) 0.3 bequerels per square centimetre of for all Class A radionuclides;
> (ii) 3 bequerels per square centimetre of for all Class B radionuclides; or
> (iii) 30 bequerels per square centimetre of for all Class C radionuclides;
> averaged over an area not exceeding 100 square centimetres.

See Appendix *7* - Classes of Nuclear Substances for a list of isotopes in each class.

Elements of a Contamination Monitoring Program

Method of Measurement

Radioactive contamination may be measured directly or indirectly. Direct measurement means the use of portable radiation detection instruments to detect both fixed and removable contamination. Direct measurement may be used when background radiation levels are negligible compared to licence criteria. Indirect measurement only detects removable contamination by means of wipe tests.

Instrument Selection

The ability of various radiation detection instruments to detect radioisotopes of interest will vary with the instrument and manufacturer. Guidance on the selection of instruments may be obtained from Environmental Health and Safety. For specific information on a particular make or model, contact the manufacturer.

Locations of Measurements

The locations that are to be monitored should be numbered on a plan of the radioisotope work area. These locations should include working surfaces (benches, countertops, fume hoods etc.), storage areas, and non-working surfaces such as floors, instruments, door handles, light switches, sink taps and telephone receivers. Several random locations should also be monitored. Too rigid a set of locations may overlook problem areas.

Instrument Checks and Calibration

Non portable instruments for counting wipes, such as liquid scintillation counters, well-crystal type gamma counters, should be routinely serviced according to the manufacturer's instructions. Keep a record of the service information and dates. A copy of this service information should be kept with your contamination monitoring records. A blank and a standard should be counted and recorded with each set of wipes. Please see Appendix 21 of this manual for a procedure demonstrating the counting of standard as a quality control method to ensure proper equipment operation.

Before monitoring for contamination, portable instruments should be given operational checks as specified by the manufacturer (battery check, response check etc.) and the background radiation level should be measured. Record the operational checks and background measurements on your contamination monitoring records. Instruments that are not operating within the parameters of the operational checks or which show anomalous background, blank or standard measurements, should not be used until their proper operation can be verified.

Instruments must be calibrated annually by a qualified service provider to ensure that the calibration is conducted in accordance with the CNSC Application Guide - Appendix Z "Regulatory Expectations for Calibration of Survey Meters".

Frequency of Monitoring

Contamination monitoring frequencies must conform to the requirements indicated on the appropriate CNSC Laboratory Rules Poster, or in a radioisotope licence condition. It is recommended that wipes be done on the same day each week to ensure that contamination monitoring requirements are met. (NOTE: This day should not be a Monday to avoid statutory holidays.)

Decontamination

Any area that is found to have non-fixed contamination exceeding the regulatory criteria must be cleaned and remonitored. If the area cannot be cleaned to meet the criteria, the contaminated area must be sealed, removed, or shielded until the criteria are met.

Monitoring Records

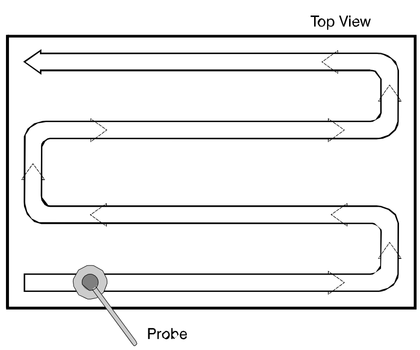
Contamination monitoring records must be kept for three years or the next CNSC inspection whichever is longer. Approval of the RSO must be obtained prior to destruction. The records must be available for inspection by the CNSC or the University Radiation and Laser Safety Officer. These records must include:

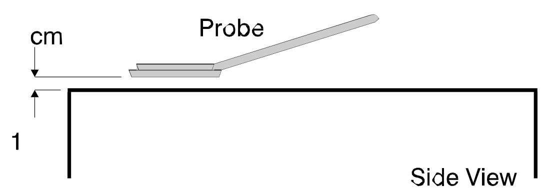
- (a) date of measurement
- (b) make an model of the instrument
- (c) monitoring locations
- (d) contamination monitoring results in Bq/cm^2 (before and after decontamination)
- (e) results of operational checks and background measurements for portable instruments.
- **(f)** blank and standard measurement results for non-portable instruments.

DIRECT MEASUREMENT OF CONTAMINATION USING PORTABLE METER

Direct Contamination Survey Technique

- Perform operational checks on the instrument. Record results of checks.
- Select a slow response time (if the metre is so equipped) and measure and record the background count rate.
- Select the response time to a fast response time and commence to survey the surfaces marked on the plan of the working area. Start at the leading edge with the metre or probe 1 cm from the surface. Use a paint brush technique (see diagrams below), this will ensure that the entire surface is surveyed. Please note that the meter is not a ‘magic wand’, therefore you must survey slowly to give the metre time to respond.
- When an increase in count rate is detected, the surveyor should change ranges (if necessary) and move the meter or probe back and forth over the source at the centre. If it is a point source, the count rate will decrease as the metre or probe moves away from the source. If it is a large area source, the cross survey technique can be used to find its extent. An accurate count rate can now be obtained by slowing down the metre response time and then subtracting the background.
- Clean the area until the instrument measurement is below the licence criteria. A reading in excess of licence criteria after repeated cleaning is an indication of fixed contamination or a high radiation background.
- Record the highest measurement for each area and the final measurement after decontamination.
- If the levels of beta and gamma contamination are high enough, they may cause the metre to go off scale. This would indicate that a dose rate measurement may be required.





DETECTOR EFFICIENCY

The detector efficiency depends upon:

- the type of detector (GM, NaI Scintillation, Proportional)
- the detector size and shape
- the distance from the detector to the radioactive material
- the radioisotope and type of radiation measured (alpha, beta, gamma radiations and their energies)
- the backscatter of radiation toward the detector (the denser the surface, the more scattering)
- the absorption of radiation before it reaches the detector (by air and the detector covering)

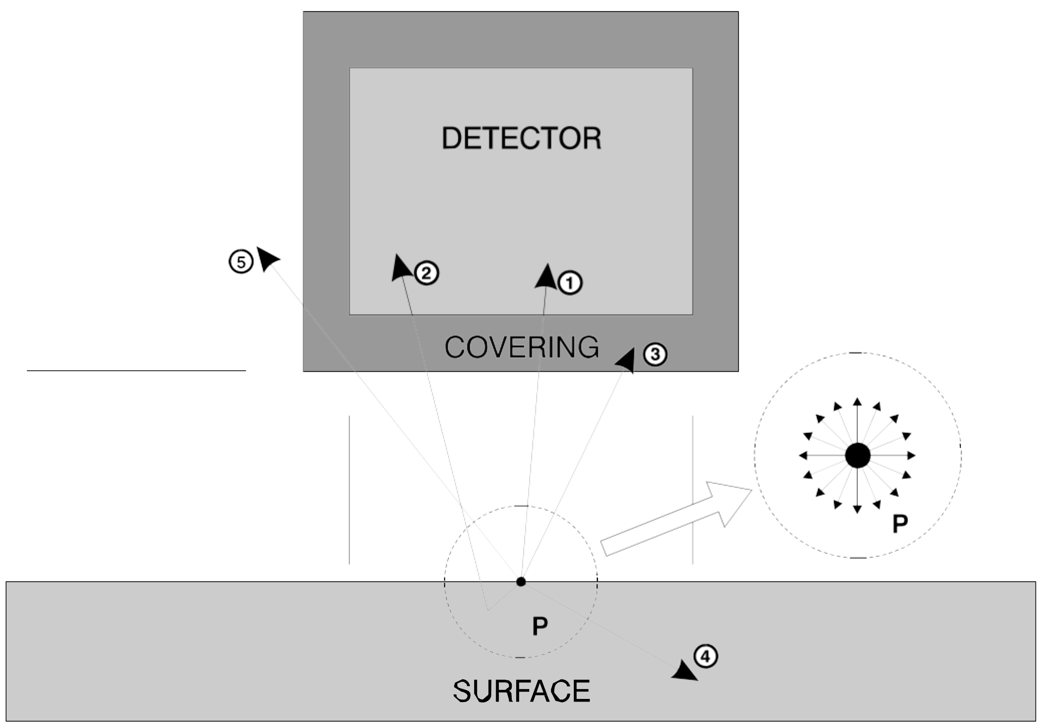
The factors effecting the efficiency are show in the diagram below.

The detector efficiency can be found by:

1. Counting a standard source of known activity with your detector.

$$\text{efficiency} = \frac{\text{(detector count rate-background count rate)}}{\text{known activity of standard source}}$$

2. Asking the manufacturer about the efficiency of the detector for specific radioisotope(s).



1. Some radiation goes directly from the radioactive material **P**, into the detector.
2. Some radiation will backscatter off the surface, into the detector.
3. Some radiation is absorbed by the detector covering.
4. Most radiation doesn't even get detected.
5. If the detector was closer, this radiation would be detected.

INDIRECT MEASUREMENT OF CONTAMINATION WITH WIPES

Indirect Contamination Measurement Technique

- Indirect removable contamination measurements are made by sampling with a wipe and measuring the activity on the wipe.
- Wipe each of the locations shown on the plan of the working area with a filter paper.
- Hold the filter paper with your thumb and forefinger and rub the smear over the surface using light pressure.
- Wipe an area of 100 cm^2 (slightly larger than the palm of your hand).
- Use only one wipe per location.
- If the wipes are counted with a contamination meter, the wipe should be smaller than or equal to the sensitive area of the detector.
- If the wipes are counted in a liquid scintillation counter, the printouts from the counter must be kept with the contamination monitoring records.
- Clean any contaminated area and remonitor.

RELATING MEASUREMENT READINGS TO REGULATORY CRITERIA

Derived Working Level (DWL) for measurements can be calculated as follows:

$$C = \frac{(N-B)}{E \times 60 \times A \times (F)}$$

Where:

C	=	Contamination Level (Bq/cm^2)
N	=	Total Counts in Counts per Minute (CPM) measured directly or on the wipe
B	=	Normal Background count rate (in CPM) from the survey instrument or on the blank)
E	=	Instrument efficiency factor (expressed as a decimal, i.e. 26% efficiency E=0.26) for the radioisotope being measured (consult the manufacturer or determine using a radioactive source with a known activity in a counting geometry similar to that used when surveying)
60	=	sec/min
A	=	area wiped (not to exceed 100 cm^2) or area of the detector in cm^2 (for direct measurements)
F	=	collection factor for the wipe (used ONLY when calculating indirect monitoring results)

If F is not determined experimentally, a value of F=.1 (i.e. 10%) shall be used

$$DWL\ (1\ Bq/cm^2) = \frac{(N-B)}{C} = \text{(cpm above background)}$$

CONTAMINATION CONTROL RECORD

PERMIT HOLDER ______________________________ PERMIT # ________

DEPARTMENT ____

ROOM # ________

SAMPLING DATE

____

ISOTOPES USED

3H_______ 14C ______

32P_______ 35S ______

22Na ______

______ ______

______ ______

Make and Model of Detector ____

Date Last Calibrated ______________________________

WIPES OR MONITORING MUST BE TAKEN AT LEAST ONCE A WEEK WHEN RADIOISOTOPES ARE IN USE.

THE RESULTS MUST BE RECORDED ON THE FORM
WEEKS WHEN RADIOISOTOPES ARE NOT IN USE MUST BE INDICATED ON THE FORM
RECORD OF CONTAMINATION CONTROL

Week Starting Background CPM _________ Monitor Date ____________

LOCATION	CPM	$Bq/cm^2/100\ cm^2$	AFTER CLEANUP	COMMENTS
1	______	______	______	
2	______	______	______	
3	______	______	______	
4	______	______	______	
5	______	______	______	
6	______	______	______	
7	______	______	______	

Week Starting Background CPM _________ Monitor Date ____________

LOCATION	CPM	$Bq/cm^2/100\ cm^2$	AFTER CLEANUP	COMMENTS
1	______	______	______	
2	______	______	______	
3	______	______	______	
4	______	______	______	
5	______	______	______	
6	______	______	______	
7	______	______	______	

Week Starting Background CPM _________ Monitor Date ____________

LOCATION	CPM	$Bq/cm^2/100\ cm^2$	AFTER CLEANUP	COMMENTS
1	______	______	______	
2	______	______	______	
3	______	______	______	
4	______	______	______	
5	______	______	______	
6	______	______	______	
7	______	______	______	

Appendix 13 – Sealed Radiation Source Leak Testing Certificate

Queen's University
Environmental Health & Safety
355 King Street West, 1st Floor, West Wing
Kingston, ON, K7L 3N6

Contact Person: Jamie Coad, RSO
Phone: (613) 533-6000 78358
Phone 24 Hours: (613) 533-6111
(Queen's Emergency Report Centre)

CNSC Licence: 07156-1-22.9

Wipe Sampler's Information

Name: ______________________________
Address: ______________________________
____
Phone: ______________________________
Signature: ______________________________

Source Information

Permit #:________________ Permit Holder: ________________
Building:________________ Room: ________________
Manufacturer: ______________________________
Serial #:________________ Model #: ________________
Isotope:________________ Activity: ________________

VIAL #	CPM	BKGR.	EFF. FACTOR	DPM	<200 Bq	>200 Bq

Wipe Measurement Information

Measured by:______________________ Date: __________
Phone: ________________

Signature: ______________________

Action to be Taken

Under 150 dpm - results to file
>150 dpm and <200 Bq: **Investigation by RSO**
>200 Bq - **isolate source and inform CNSC.**

After receiving you permit the following steps must be followed:

Signage and Labelling

All laboratories listed on your permit must have a copy of the current permit posted in a conspicuous place and appropriate signage and labelling of radioactive materials as described below (Radiation Protection Regulations (SOR/2000-203) amended 2017-09-22). All doors which are used by personnel to enter the laboratory must have a 'Rayonnement/Danger Radiation' sign affixed to them. The sign must be completed with the Permit Holders name and telephone number and indicate to follow the personnel entry procedures required by the licence.

The CNSC poster 'Basic Level Use of Unsealed Nuclear Substances' or 'Intermediate Level Use of Unsealed Nuclear Substances' or 'High Level Use of Unsealed Nuclear Substances' must be posted in each laboratory where unsealed sources are used.

Areas where radioisotope work is to be carried out must be so marked with radiation signage as described below. Equipment and storage areas must also have a radiation warning sign affixed to them as described below.

High Level labs must have the 'High Laboratory Users's Exit Log" posted, and metering equipment present to monitor personnel leaving the laboratory (APPENDIX 15)

Labelling of Containers and Devices
Radiation Protection Regulations (SOR/2000-203) amended 2017-09-22

(1) No person shall possess a container or device that contains a radioactive nuclear substance unless the container or device is labelled with

(a) the radiation warning symbol set out in Schedule 3 and the words "*RAYONNEMENT* — DANGER — RADIATION"; and

(b) the name, quantity, date of measurement and form of the nuclear substance in the container or device.

(2) Subsection (1) does not apply in respect of a container or device

(a) that is an essential component for the operation of the nuclear facility at which it is located;

(b) that is used to hold radioactive nuclear substances for current or immediate use and is under the continuous direct observation of the licensee;

(c) in which the quantity of radioactive nuclear substances is less than or equal to the exemption quantity; or

(d) that is used exclusively for transporting radioactive nuclear substances and labelled in accordance with the *Packaging and Transport of Nuclear Substances Regulations, 2015*.

SOR/2015-145, s. 46.

Posting of Signs at Boundaries and Points of Access

Radiation Protection Regulations (SOR/2000-203) amended 2017-09-22

Every licensee shall post and keep posted, at the boundary of and at every point of access to an area, room or enclosure, a durable and legible sign that bears the radiation warning symbol set out in Schedule 3 and the words “RAYONNEMENT-DANGER-RADIATION”, if

(a) there is a radioactive nuclear substance in a quantity greater than 100 times its exemption quantity in the area, room or enclosure; or

(b) there is a reasonable probability that a person in the area, room or enclosure will be exposed to an effective dose rate greater than 25 μSv/h.

SOR/2007-208, s. 9.

post and keep posted, in a visible location at every personnel access opening to any equipment fitted with a radiation device, a durable and legible sign that bears

(i) the radiation warning symbol set out in Schedule 3 to the *Radiation Protection Regulations* and the words “RAYONNEMENT — DANGER — RADIATION”, and

(ii) the requirement to follow the personnel entry procedures required by the licence.

Use of Radiation Warning Symbol

Radiation Protection Regulations (SOR/2000-203) amended 2017-09-22

Whenever the radiation warning symbol set out in Schedule 3 is used,

(a) it shall be

(i) fully visible,

(ii) of a size appropriate for the size of the container or device to which it is affixed or attached, or the area, room or enclosure in respect of which it is posted,

(iii) in the proportions depicted in Schedule 3, and

(iv) oriented with one blade pointed downward and centred on the vertical axis; and

(b) no wording shall be superimposed on it.

SOR/2007-208, s. 10.

Frivolous Posting of Signs

No person shall post or keep posted a sign that indicates the presence of radiation, a nuclear substance or prescribed equipment at a place where the radiation, nuclear substance or prescribed equipment indicated on the sign is not present.

Metering Equipment

Meters, if required must be obtained. Efficiencies (for the isotopes that will be used in the laboratory) for all meters and scintillation/gamma counters must be obtained.

Training

All laboratory personnel must be registered in the next available Radiation Training Course, put on by the Department of Environmental Health and Safety.

Flow Chart

The one instrument that links the entire record-keeping process is the flow sheet. Beginning with the amount of product used and ending with an accurate record of the waste(s) produced. A flow sheet must be developed and kept for each and every procedure that is to be carried out in the laboratory. In most cases the protocol will have to be investigated only one time on a step-wise basis so that the flow sheet can provide a record of the movement of isotopic activity through the procedure. Direct measurements (printouts must be kept) should be made of the activity of all side and end products and must be detailed in writing. Where appropriate, manufacturers specifications for percentage of incorporation may be used, however, direct measurements are generally more accurate. See examples in Appendix 10.

Inventory Records

Inventory records (see APPENDIX 9) must be set up. One record is required for each vial. Copies of the purchase order (if available), packing slips and any Transportation of Dangerous Goods documents must be attached to the form.

Waste Records

Waste logs must be kept to detail all wastes disposed of via Environmental Health & Safety. Separate logs should be made for individual bags of waste. Information contained in the waste log should be cross-referenced with information from the flow sheet. Logs must be sufficiently detailed so that the activity of the contents of any given bag of waste can be accurately demonstrated.

Contamination Monitoring Records

Contamination Monitoring Records (see APPENDIX 12) must be set up. Contamination monitoring must be done at least weekly when isotopes are being used. During those periods when there is no isotope use, this inactivity must be so indicated on the forms. Printouts from scintillation/gamma counters must be attached to the Record of Contamination Monitoring.

Use of Radioisotopes in Live Animals

A lab specific SOP will be developed to describe the procedures involved in the administration of radioisotopes to live animals for each type of administration. Live animals containing radioisotopes must be housed in appropriately marked containers in designated areas. Any materials that are not disposable such as animal caging, including bottles, and cage covers, will remain in the designated radioactive room until swipe tests show radioisotope levels decreased to less than 3 times background (or decontaminated, depending on the radioisotope in use). All waste products (bedding, faeces, etc.) must be treated as radioactive waste.

USER'S EXIT LOG FOR HIGH LEVEL RADIOISOTOPE LABORATORIES

PERMIT HOLDER ________________BUILDING __________ ROOM # ____________

			CONTAMINATION CHECK MARK OK or N/A		
DATE	TIME	NAME	HANDS	LAB COAT	SHOES

Before a Permit Holder leaves the University, moves their laboratory, or wishes to cancel their internal permit their laboratories must be decommissioned as per Environmental Health and Safety Policy SOP-LAB-04 (Laboratory Decommissioning) and CNSC Licence condition 2571 described below:

LC 2571 Decommissioning

The licensee shall ensure that prior to decommissioning any area, room or enclosure where the licensed activity has been conducted.

(a) the non-fixed contamination for nuclear substances listed in the licence application guide table titled "Classification of Radionuclides" does not exceed:
   (i) 0.3 becquerels per square centimetre for all Class A radionuclides;
   (ii) 3 becquerels per square centimetre for all Class B radionuclides; and
   (iii) 30 becquerels per square centimetre for all Class C radionuclides; averaged over an area not exceeding 100 square centimetres;

(b) the release of any area, room or enclosure containing fixed contamination, is approved in writing by the Commission or person authorized by the Commission;

(c) all nuclear substances and radiation devices have been transferred in accordance with the conditions of this licence; and

(d) all radiation warning signs have been removed or defaced.

Level of Radioisotope Laboratory	**Permissible Quantity of Radioactivity**
Storage	Stored without manipulation
Basic	Does Not Exceed 5 times corresponding ALI
Intermediate	Does Not Exceed 50 times corresponding ALI
High	Does Not Exceed 500 times corresponding ALI
Containment	Exceeds 500 times corresponding ALI

* See Appendix 5 Annual Limit of Intake (ALI)

RADIOTOXICITY OF RADIOISOTOPES*

Table 1

Radiotoxicity of the Individual Radionuclides	Permissible Level of Activity (for Normal Chemical Operations)
Very High	5 MBq (135 µCi)
High	500 MBq (13.5 mCi)
Moderate	** 5 GBq (135 mCi)
Slight	50 GBq (1.35 Ci)

* Radiotoxicity is defined as potential toxicity following ingestion, inhalation and absorption.

** Except for Mo/^{99m}Tc generators and ^{99m}Tc eluate, for which the permissible activity is 100 GBq (3Ci)

Table 2

Relative Radiotoxicity* and Physical
Half Life of some Radioisotopes

1. Very High Radiotoxicity

Actinium 227	(21.2 years)
Americium 241	(458 years)
Americium 243	(7,650 years)
Californium 249	(360 years)
Californium 250	(10 years)
Californium 252	(2.6 years)
Curium 242	(163 days)
Curium 243	(32 years)
Curium 244	(17.6 years)
Curium 245	(9,320 years)
Curium 246	(5,480 years)
Lead 210	(21 years)
Neptunium 237	(2.1×10^6 years)
Plutonium 238	(89 years)
Plutonium 239	(2.4×10^4 years)
Plutonium 240	(6,760 years)
Plutonium 241	(13 years)
Plutonium 242	(3.8×10^5 years)
Polonium 210	(138 days)
Protactinium 231	(3.2×10^4 years)
Radium 223	(11.7 days)
Radium 226	(1,620 years)
Radium 228	(6.7 years)
Thorium 227	(18.2 days)
Thorium 228	(1.9 years)
Thorium 230	(7.6×10^4 years)
Uranium 230	(20.8 days)
Uranium 232	(73.6 years)
Uranium 233	(1.6×10^5 years)
Uranium 234	(2.5×10^5 years)

*Appendix I, "Safety Code; Laboratory Facilities for Handling Radioisotopes" Bulletin RPB-SC-12, Health and Welfare Canada 1976

2. High Radiotoxicity

Actinium 228	(6.1 hours)
Antimony 124	(60 days)
Antimony 125	(2.7 years)
Astatine 211	(7.2 hours)
Barium 140	(12.8 days)
Berkelium 249	(314 days)
Bismuth 207	(30 years)
Bismuth 210	(5.0 days)
Cadmium 115m	(43 days)
Calcium 45	(165 days)
Cerium 144	(285 days)
Cesium 134	(2.1 years)
Cesium 137	(30 years)
Chlorine 36	($3x10^5$years)
Cobalt 56	(77 days)
Cobalt 60	(5.3 years)
Europium 152	(13 years)
Europium 154	(16 years)
Hafnium 181	(45 days)
Indium 114m	(50 days)
Iodine 124	(4.2 days)
Iodine 125	(57 days)
Iodine 126	(132.2 days)
Iodine 131	(8.0 days)
Iodine 133	(21 hours)
Iridium 192	(74 days)
Lead 212	(10.6 hours)
Manganese 54	(314 days)
Protactinium 230	(17 days)
Radium 224	(3.6 days)
Ruthenium 106	(1.0 years)
Scandium 46	(84 days)
Silver 110m	(249 days)
Sodium 22	(2.6 years)
Strontium 89	(50 days)
Strontium 90	(28 years)
Tantalum 182	(115 days)
Tellurium 127m	(105 days)
Tellurium 129m	(33 days)
Terbium 160	(73 days)
Thorium 234	(24.1 days)
Thulium 170	(127 days)
Uranium 236	($2.4x10^7$ years)
Yttrium 91	(59 days)
Zirconium 95	(65 days)
Thallium 204	(3.8 years)

3. Moderate Radiotoxicity

Antimony 122	(2.8 days)
Argon 41	(1.8 hours)
Arsenic 73	(76 days)
Arsenic 74	(18 days)
Arsenic 76	(26.5 hours)
Arsenic 77	(39 hours)
Barium 131	(11.6 days)
Beryllium 7	(53 days)
Bismuth 206	(6.2 days)
Bismuth 212	(60.6 minutes)
Cadmium 109	(1.3 years)
Cadmium 115	(2.3 days)
Calcium 47	(4.5 days)
Carbon 14	(5730 years)
Gerium 141	(32.5 days)
Cerium 143	(33 hours)
Cesium 131	(9.7 days)
Cesium 136	(13 days)
Chlorine 38	(37 minutes)
Chromium 51	(27.8 days)
Cobalt 57	(267 days)
Cobalt 58	(71 days)
Copper 64	(12.9 hours)
Dysprosium 165	(2.3 hours)
Dysprosium 166	(80 hours)
Erbium 169	(9.4 days)
Erbium 171	(7.5 hours)
Europium 152m	(9.2 hours)
Europium 155	(1.7 years)
Fluorine 18	(111 minutes)
Gadolinium 153	(200 days)
Gadolinium 195	(18 hours)
Gallium 72	(14.1 hours)
Gold 196	(6.2 days)
Gold 198	(64.8 hours)
Gold 199	(3.15 days)
Holmium 166	(9×10^4 years)
Indium 115m	(4.4 hours)
Iodine 130	(12.5 hours)
Iodine 132	(2.3 hours)
Iodine 134	(53 minutes)
Iodine 135	(6.7 hours)
Iridium 190	(12 days)
Iridium 194	(19 hours)
Iron 52	(8.3 hours)
Iron 55	(2.7 years)
Iron 59	(45 days)
Krypton 85m	(4.4 hours)
Krypton 87	(78 minutes)
Lanthanum 140	(40.2 hours)
Lead 203	(52 hours)
Lutetium 177	(6.8 days)
Manganese 52	(5.7 days)
Manganese 56	(2.6 hours)
Mercury 197m	(24 hours)
Mercury 197	(65 hours)
Mercury 203	(47 days)
Molybdenum 99	(66 hours)
Meodymium 147	(11.1 days)
Neodymium 149	(1.8 hours)
Neptunium 239	(2.4 days)
Nickel 63	(92 years)
Nickel 65	(2.6 hours)
Niobium 93m	(3.7 years)
Niobium 95	(35 days)
Osmium 185	(94 days)
Osmium 191	(15 hours)
Osmium 193	(32 hours)
Palladium 103	(17 days)
Palladium 109	(13.5 hours)
Phosphorus 32	(14.3 days)
Phosphorus 33	(25.3 days)
Platinum 191	(3.0 days)
Platinum 193	(500 years)
Platinum 197	(2.0 hours)
Potassium 42	(12.4 hours)
Potassium 43	(22 hours)
Praseodymium 142	(19.2 hours)
Praseodymium 143	(13.7 days)
Promethium 147	(2.5 years)
Promethium 149	(53 hours)
Protactinium 233	(27.4 days)
Radon 220	(56 seconds)
Radon 222	(3.8 days)
Rhenium 183	(70 days)
Rhenium 186	(90 hours)
Rhenium 188	(17 hours)
Rhodium 105	(36 hours)
Rubidium 86	(18.7 days)
Ruthenium 97	(2.9 days)
Ruthenium 103	(40 days)
Ruthenium 105	(4.4 hours)

3. Moderate Radiotoxicity (cont'd)

Samarium 151	(90 years)
Samarium 153	(46.7 hours)
Scandium 47	(3.4 days)
Scandium 48	(44 hours)
Selenium 75	(120 days)
Silicon 31	(2.6 hours)
Silver 105	(40 days)
Silver 111	(7.5 days)
Sodium 24	(15 hours)
Strontium 85	(64 days)
Strontium 91	(9.7 hours)
Sulfur 35	(87 days)
Technetium 96	(43 days)
Technetium 97m	(91 days)
Technetium 97	($2.6x10^6$ years)
Technetium 99	($2.1x10^5$ years)
Tellerium 125m	(58 days)
Tellerium 127	(9.3 hours)
Tellerium 129	(67 minutes)
Tellerium 131m	(1.2 days)
Tellerium 132	(78 hours)
Thallium 200	(26 hours)
Thallium 201	(73 hours)
Thallium 202	(12 days)
Thorium 231	(25.6 hours)
Thulium 171	(1.9 years)
Tin 113	(118 days)
Tin 125	(9.4 days)
Tungsten 181	(130 days)
Tungsten 185	(74 days)
Tungsten 187	(24 hours)
Vanadium 48	(16.1 days)
Xenon 135	(9.2 hours)
Ytterbium 175	(4.2 days)
Yttrium 90	(64.2 hours)
Yttrium 92	(3.5 hours)
Yttrium 93	(10.1 hours)
Zinc 65	(245 days)
Zinc 69m	(14 hours)
Zirconium 97	(17 hours)

4. Slight Radiotoxicity

Argon 37	(34.3 days)
Cesium 134m	(2.9 hours)
Cesium 135	($2x10^6$ years)
Cobalt 58m	(9 hours)
Germanium 71	(11 days)
Hydrogen 3	(12.3 years)
Indium 113m	(1.7 hours)
Iodine 129	($1.6x10^7$ years)
Krypton 85	(10.4 years)
Nickel 59	($8x10^4$ years)
Niobium 97	(72 minutes)
Osmium 191m	(14 hours)
Oxygen 15	(2 minutes)
Platinum 193m	(4.4 days)
Platinum 197m	(82 minutes)
Rhenium 187	($4x10^{10}$ years)
Rhodium 103m	(57 minutes)
Rubidium 87	($5x10^{10}$ years)
Samarium 147	($1.1x10^{11}$ years)
Strontium 85m	(70 minutes)
Technetium 96m	(52 minutes)
Technetium 99m	(6.0 hours)
Thorium 232	($1.4x10^{10}$ years)
Natural Thorium	
Uranium 235	($7x10^8$ years)
Uranium 238	($4.5x10^9$ years)
Natural Uranium	
Xenon 131m	(12 days)
Xenon 133	(5.3 days)
Yttrium 91m	(50 minutes)
Zinc 69	(55 minutes)

Effective Dose Limits

Item	Column 1 Person	Column 2 Period	Column 3 Effective Dose (mSv)
1	Nuclear energy worker, including a female nuclear energy worker who is breastfeeding and a female nuclear energy worker who is pregnant but who has not yet informed the licensee in writing that she is pregnant	**(a)** One-year dosimetry period	50
		(b) Five-year dosimetry period	100
2	Pregnant nuclear energy worker who has informed the licensee in writing that she is pregnant	Balance of the pregnancy starting from the date on which the licensee has been informed of the pregnancy	4
3	Person who is not a nuclear energy worker	One calendar year	1

Equivalent Dose Limits

Item	Column 1 Organ or Tissue	Column 2 Person	Column 3 Period	Column 4 Equivalent Dose (mSv)
1	Lens of an eye	**(a)** Nuclear energy worker	One-year dosimetry period	50
		(b) Any other person	One calendar year	15
2	Skin	(a) Nuclear energy worker	One-year dosimetry period	500
		(b) Any other person	One calendar year	50
3	Hands and feet	(a) Nuclear energy worker	One-year dosimetry period	500
		(b) Any other person	One calendar year	50

See next page for poster for handling packages containing nuclear substances.

GUIDELINES FOR HANDLING PACKAGES CONTAINING NUCLEAR SUBSTANCES

Identifying Packages Containing Nuclear Substances

The packaging and labeling of nuclear substances is governed by the Canadian Nuclear Safety Commission's *Packaging and Transport of Nuclear Substances (PTNS) Regulations*. Nuclear substances may be shipped in "Excepted Packages", "Type A" or "Type B" packages, "Industrial Packages I, II, III", and packages for "Fissile Material". The "radioactive" category labels also show radiation dose rates.

On Excepted Packages, no external labeling is required, and the safety mark "RADIOACTIVE" must be visible upon opening the package. The radiation level at any point on the external surface of the package must not exceed 5 µSv/h. All other packages must be categorized by radiation level and display the corresponding radiation warning labels as follows:

Category I-WHITE
Does not exceed 5 µSv/h at any location on the external surface of the package

Category II-YELLOW
Does not exceed 500 µSv/h at any location on the external surface of the package and the transport index does not exceed 1.

Category III-YELLOW
Does not exceed 2 mSv/h at any location on the external surface of the package and the transport index does not exceed 10.

The transport index is the maximum radiation level in microsieverts per hour at one metre from the external surface of the package, divided by 10.
Example: 1 µSv/h (0.1 mrem/h) at 1 m equals a TI = 0.1.

Upon receipt of a package containing nuclear substances, keep your distance. Examine the package for damage or leakage. If the package is damaged or leaking, contain and isolate it to minimize radiation exposure and contamination, and comply with Section 19 of the PTNS *Regulations*.

Opening Packages Containing Nuclear Substances

Radiation Safety Officer	Phone Number

1. If an appropriate survey monitor is available, monitor the radiation fields around the package. Note any discrepancies.
2. Avoid unnecessary direct contact with unshielded containers.
3. Verify the nuclear substance, the quantity, and other details with the information on the packing slip and with the purchase order. Log the shipment details and any anomalies in the inventory record.
4. Report any anomalies (radiation levels in excess of the package labeling, incorrect transport index, contamination, leakage, short or wrong shipment) to the Radiation Safety Officer.

When opening packages containing unsealed nuclear substances, additional steps should be taken:

5. Wear protective clothing while handling the package.
6. If the material is volatile (unbound iodine, tritium, radioactive gases, etc.) or in a powder form, open the package in a fume hood.
7. Open the outer package and check for possible damage to the contents, broken seals, or discoloration of packing materials. If the contents appear to be damaged, isolate the package to prevent further contamination and notify the Radiation Safety Officer.
8. If no damage is evident, wipe test the inner package or primary container which holds the unsealed nuclear substance. If contamination is detected, monitor all packaging and, if appropriate, all locations in contact with the package, for contamination. Contain the contamination, decontaminate, and dispose in accordance with the conditions of the Nuclear Substances and Radiation Devices licence.

For more information, contact: Directorate of Nuclear Substance Regulation, Canadian Nuclear Safety Commission, P.O. Box 1046, Station B, Ottawa, ON K1P 5S9. Telephone: 1-888-229-2672. Fax: (613) 995-5086.

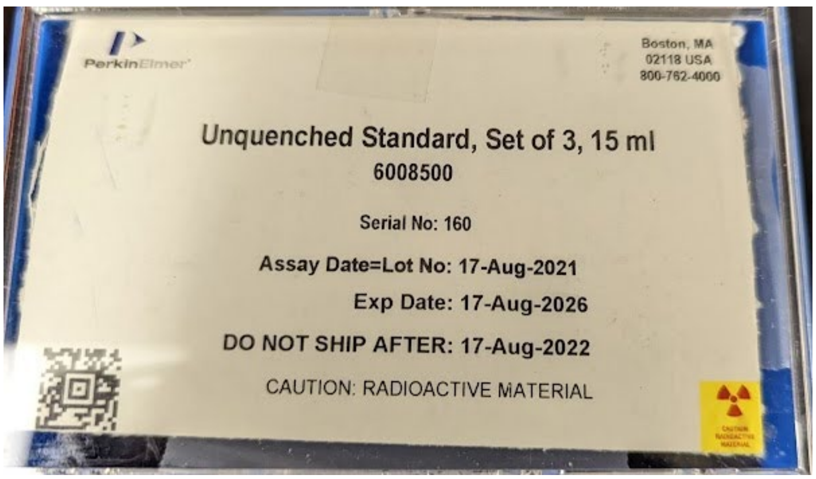
Canada

Appendix 21 – Contamination Measurement Quality Control Verification Procedure

Liquid Scintillation Counter (LSC) Routine Quality Control Verification Procedure
Instruments must be calibrated annually by a qualified service provider to ensure that the calibration is conducted in accordance with the CNSC Application Guide - Appendix Z "Regulatory Expectations for Calibration of Survey Meters".

This quality control verification should be completed and documented before any licence required measurement is made on a liquid scintillation counter at Queen's University.

1. Run the following calibration standards on the LSC.



2. Calculate the current activities of the standards including decay as per the example calculations below.

Std Assay Date: Aug 17, 2021

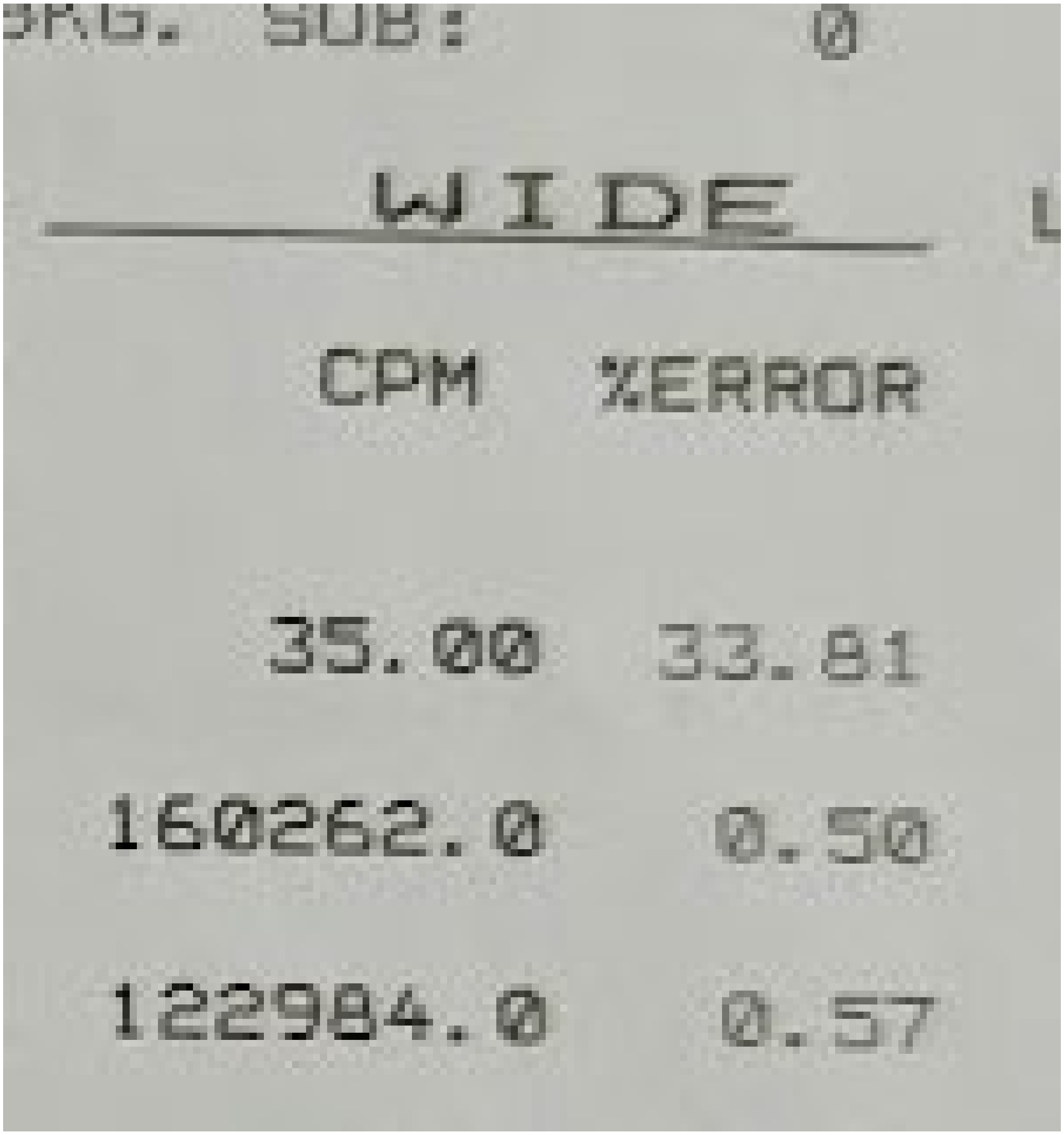
3H Std Activity = $\frac{275\,500 \text{ DPM}}{60 \text{ sec}}$ = 4592 Bq

($t_{1/2}$ = 12.33 yr) $\bar{w}$ decay = 4295 Bq

14C Std Activity = $\frac{128\,100 \text{ DPM}}{60 \text{ sec}}$ = 2135 Bq

($t_{1/2}$ = 5730 yr) $\bar{w}$ decay = 2135 Bq

3. Use the measured cpm values (wide channel) to calculate the measured activities for the 3H and 14C standards. Compare measured activities to the calculated activities in step 2. (Example LSC Data Set Below #1 = BKG, #2 = 3H std, #3 = 14C std)

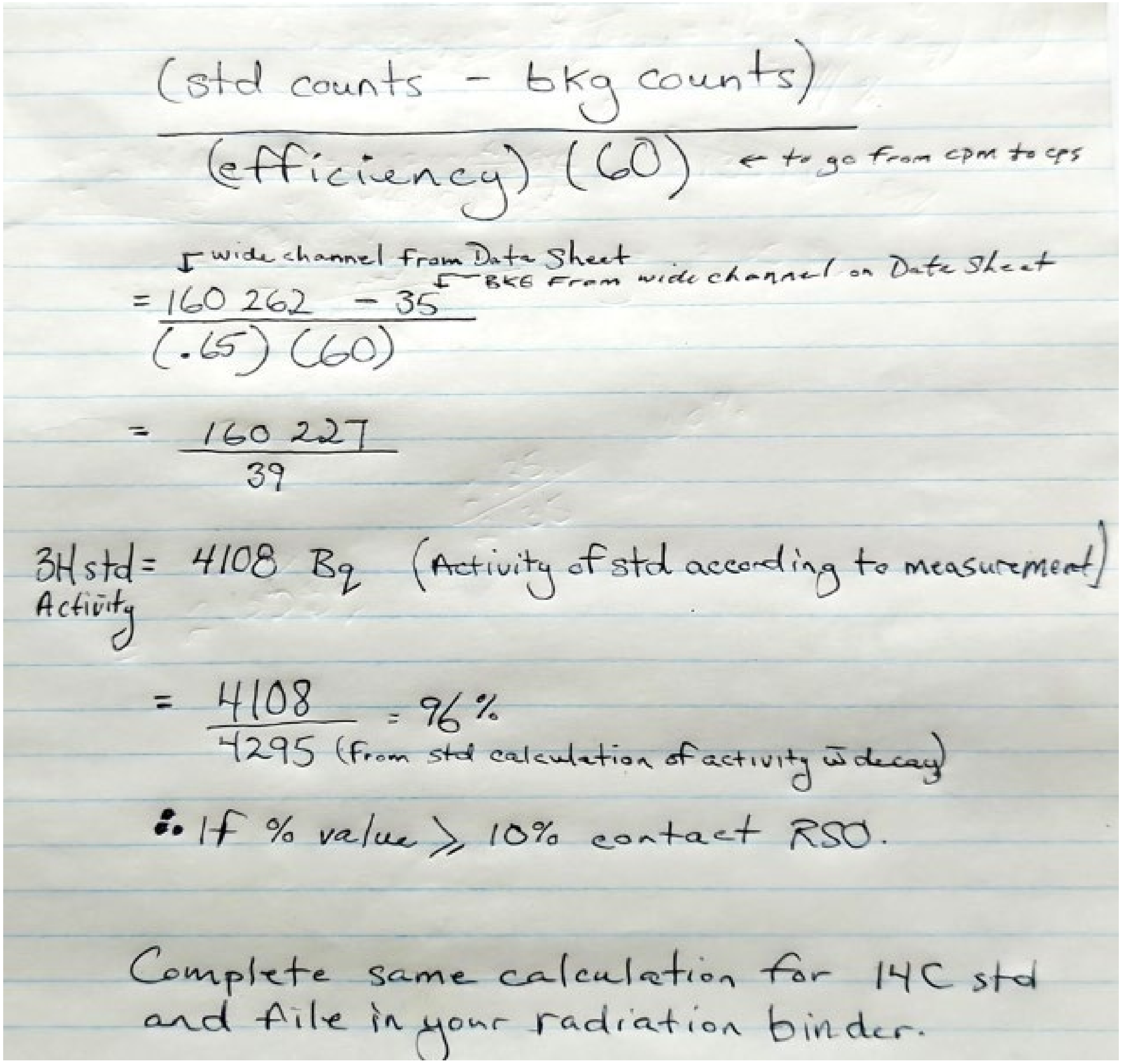


BKG. SUB: 0

WIDE

CPM	%ERROR
35.00	33.81
160262.0	0.50
122984.0	0.57

4. Calculation showing indirect measurement of count rate to activity.



$$\frac{(\text{std counts} - \text{bkg counts})}{(\text{efficiency})(60)}$$ ← to go from cpm to cps

↓ wide channel from Data Sheet

↓ BKG from wide channel on Data Sheet

$$= \frac{160\,262 - 35}{(.65)(60)}$$

$$= \frac{160\,227}{39}$$

^3H std Activity = 4108 Bq (Activity of std according to measurement)

$$= \frac{4108}{4295} = 96\%$$

4295 (from std calculation of activity w/ decay)

∴ If % value > 10% contact RSO.

Complete same calculation for 14C std and file in your radiation binder.

5. The count rate to activity calculation must be within 10% of the calculated standard activity with decay. If calculated activities are within 10% of the respective standards the quality control (QC) is considered acceptable. If the QC is not acceptable, the process should be completed again. If the QC measurements are still unacceptable, the RSO should be contacted and the instrument shall be investigate to determine if a service technician needs to be contacted.

Direct Measurement (Portable Meter) Routine Quality Control Verification Procedure

Instruments must be calibrated annually by a qualified service provider to ensure that the calibration is conducted in accordance with the CNSC Application Guide - Appendix Z "Regulatory Expectations for Calibration of Survey Meters".

This quality control verification should be completed and documented before any licence required measurement is made with a portable meter at Queen's University.

1. Calculate the activity of a sealed check source.

2. Use the portable meter to count the source with the probe at approximately 1cm from the source without touching it, in the count mode allowing for slow response time. Once the reading has stabilized, record the counts per minute and subtract the background counts measured in the area.

3. The efficiency will be needed for the check source used and the meter/probe combination. It is best to obtain this information from the manufacturer of the measurement instrument. The RSO can assist with this if necessary. Once all this information has been obtained, the following equation is used.

RELATING CPM READING TO ACTIVITY OF CHECK SOURCE

Calculated activity of the check source including decay [Bq] =

$$\frac{\text{(detector count rate)} - \text{(background count rate)}}{\text{60 sec x Efficiency obtained from manufacturer (in decimal form – 26\%=0.26)}}$$

4. The activity calculation must be within 10% of the calculated check source activity with decay. If the measured activity is within 10% of the check source activity, the quality control (QC) is considered acceptable. If the QC is not acceptable, the process should be completed again. If the QC measurements are still unacceptable, the RSO should be contacted and the instrument shall be investigate to determine if service is required.