



**RADIATION SAFETY POLICIES
FOR
LAURENTIAN UNIVERSITY**

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TABLE OF CONTENTS

	<u>Page</u>
1. Purposes of the Radiation safety policy manual at Laurentian University.....	1
2. Responsibilities - General.....	1
2.1 Overall responsibilities	1
2.2 Organizational structures	2
2.2.1. Radiological safety	2
2.2.2. Health and safety committee.....	3
2.3 Other centers	3
2.4 Revisions to the RSP.....	4
3. Authority and Responsibilities.....	5
3.1 University and Faculty level.....	5
3.1.1 The Manager, Health and Safety:	5
3.1.2 The Dean, Faculty of Science and Engineering:.....	5
3.2 The Radiation Safety Officer (RSO):	5
3.3 The Associate RSO:.....	6
3.4 The License Holders:	6
3.5 The Laboratory Supervisors:	6
3.6 The Radioisotope Workers:	7
3.7 The Purchasing personnel:.....	7
3.8 The Receiving personnel:	7
3.9 The Dosimetry coordinator:.....	7
3.10 Delegation of Responsibility by permit holders or investigators	7
3.11 Users of X-ray Equipment	8
4. General discussion of Radiological Hazards	8
4.1 Types of radiation	8
4.2 Internal Radiological Hazard	9
4.3 External Radiological Hazard.....	9
4.4 Units.....	9
4.5 Natural and man-made radiation.....	10
4.6 Allowable dose	10
5. Conduct of Operations	12
5.1 License management.....	12
5.1.1 Obtaining an internal license	12
5.1.2 Temporary licenses	12
5.1.3 Change in Status	12
5.1.4 Routine inspections.....	13
5.2 Training.....	13
5.2.1 Radiation Protection Training.....	13
5.2.2 Laboratory-specific Radioisotope Protocol Training	13
5.2.3 Support staff and janitorial training.....	13
5.3 Inventory Limits and Inventory Control.....	13

5.4	Posting of signs	14
5.4.1	The Radiation Warning Symbol	14
5.4.2	Frivolous Posting of Signs	14
5.4.3	Posting of signs on devices or containers	14
5.4.4	Posting of Signs at Boundaries and Points of Access	15
5.5	Access and control of Nuclear Substances	15
5.6	Leak testing of sources	15
5.7	Modifying factors	16
5.8	Work Control	16
5.9	Standard Practices, GLP and ALARA	17
5.10	Use of Radiation Protection Instruments	17
5.11	Movement of Sources, Materials, and Equipment	18
5.12	Contamination control and decommissioning	18
5.13	Waste Management	19
5.14	Dosimetry	19
5.15	Assistance from RSO	20
5.16	Transport and packaging	20
6.	References	21

APPENDIX

	<u>Page</u>
Appendix A: Radiation Dose Limits	A-1
Appendix B: Measurement Units Conversion Table	B-1
Appendix C: Classification of Laboratories or Working Places	C-1
Appendix D: Regulatory Quantities for Typical Radionuclides	D-1
Appendix E: Modifying factors	E-1
Appendix F: Radiotoxicity of radionuclides	F-1
Appendix G: Guide to Good Laboratory Practices (GLP)	G-1
Appendix H: Procedures in case of upset, emergency or other non-routine events	H-1
Appendix I: Self-Verification Measurements (SVMs)	I-1
Appendix J: Example of Radioisotope Log sheet	J-1
Appendix K: Radiation warning signs	K-1
Appendix L: Checklist for routine inspections	L-1
Emergency numbers	Back Page

1. Purposes of the Radiation safety policy manual at Laurentian University

This Radiation safety policy (RSP) for Laurentian University describes the general policies on the procurement, the safe use of radioisotopes for research purposes, and the storage and disposal of radioactive wastes.

Purposes:

- To provide the policies for the safety aspects and the use of radioisotopes at Laurentian University. The RSP Document is an integral part of the University's radioisotope license, and as such, it is documented with the Canadian Nuclear Safety Commission (CNSC).
- To complement the University safety policies which are already in place [1, 2].

The current RSP Document does not address specific detailed laboratory procedures. It is expected, however, that specific procedures comply with the general principles outlined in the RSP document, and other procedures generally accepted for safety.

All personnel are expected to comply with the University guidelines for safety, including the radioisotope safety regulations. This guide for Laurentian University is modeled after, and is consistent with other guides [3-6].

2. Responsibilities - General

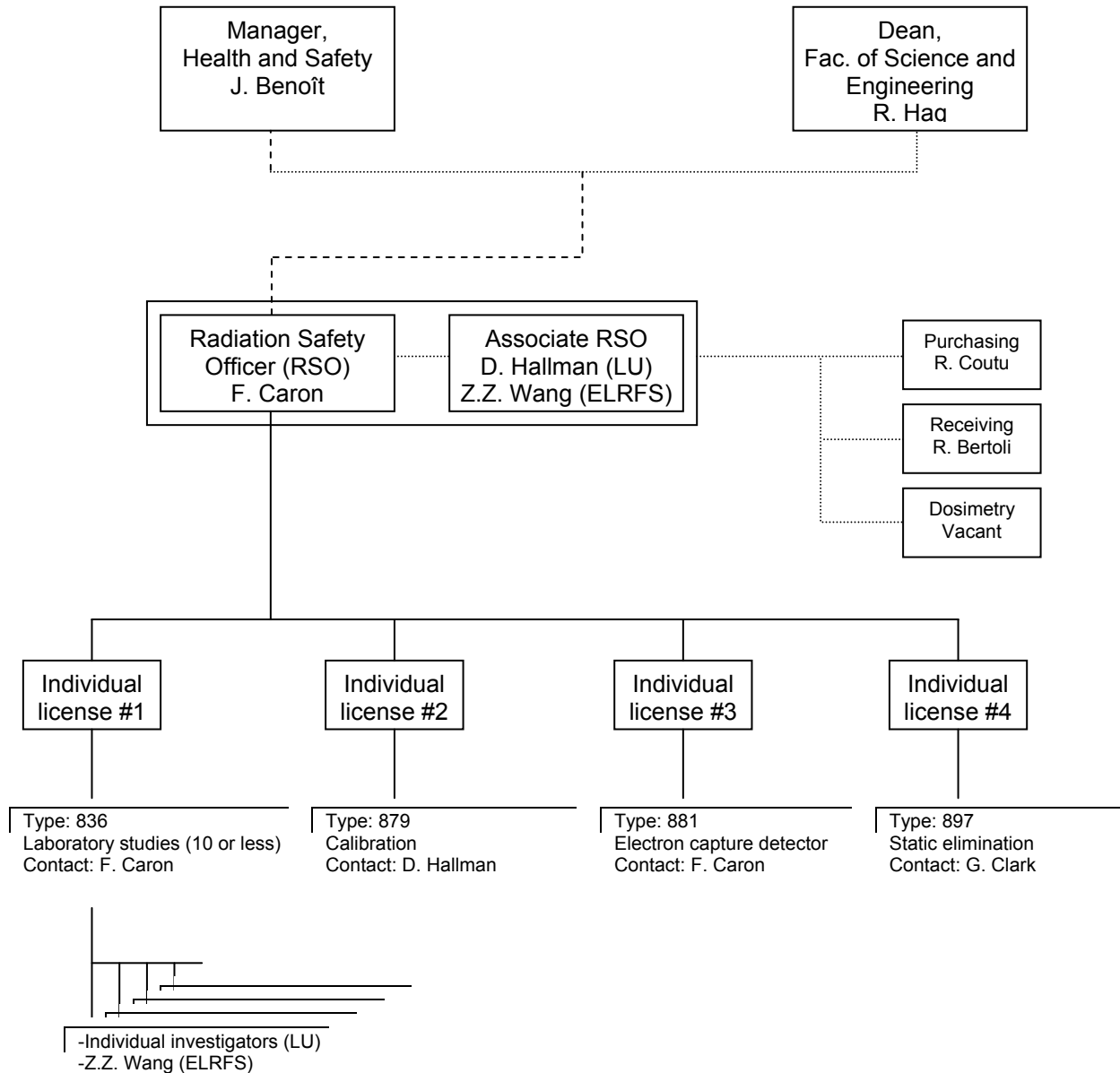
2.1 Overall responsibilities

The management of the RSP is by the Radiation Safety Officer (RSO). The RSO reports to the Manager, Health and Safety, Laurentian University, and the Dean of Science and Engineering on matters of radiological safety. The Manager, Health and Safety, and the Dean of Science and Engineering can advise the RSO on the consistency of this RSP on University safety policy. The RSO is the technical representative of the University to the CNSC for compliance matters. The individual License Holders are responsible for their permit before the CNSC, and must inform the RSO of all direct dealings with the CNSC. The individual License Holders respond to the RSO for radiation safety matters, while, in the situation of a consolidated license, the individual laboratory supervisors respond to the primary License Holder.

2.2. Organizational structures

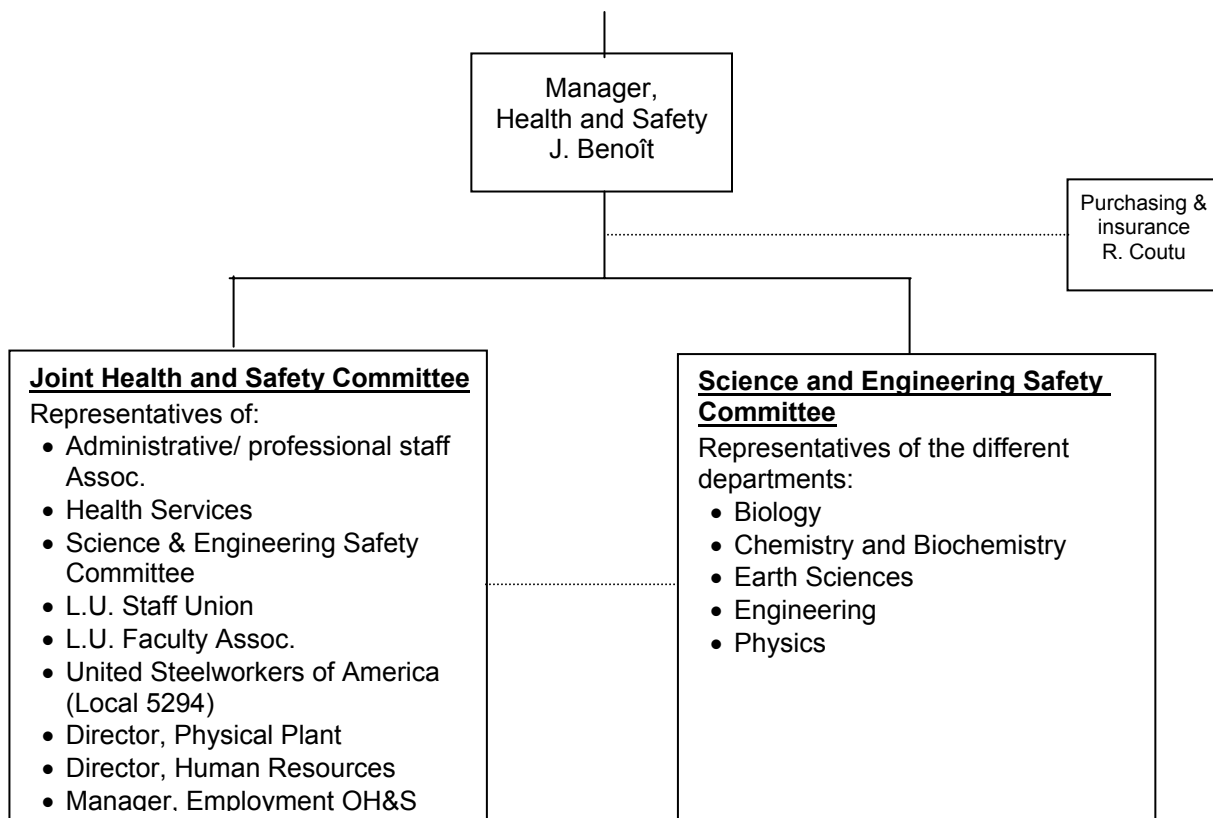
2.2.1. Radiological safety

The flowchart below shows the University's organizational structure for the purpose of radiological safety.



2.2.2. Health and safety committee

This is the composition of the joint health and safety committee, based on the description outlined in the Laurentian University Laboratory safety handbook [2], and upon consultation with the chairs of the Safety committees below.



The different department committees (e.g., Chemistry & Biochemistry, Biology, etc.), have different schedules and internal structures. Representatives of these committees can also be present on the joint Health and Safety committee. It is not unusual that members of a committee sit on other committees.

2.3 Other centers

Other organizations and research centers have formal links with Laurentian University. One of these organizations, such as the Elliot Lake Research Field Station (ELRFS), has internal radiation safety policies and procedures (ERL-QAP-11) that complement the current Policy document. Those procedures are specific to a need and generally fall under “Laboratory-specific procedures”. These procedures are consistent, and they serve as a complement to this Policy

document. Other research centers may decide to draw their own policies, however it will be up to these centers to ensure their procedures are consistent with the current document.

2.4 Revisions to the RSP

The RSP should be effective for the normal duration of a license (5 years). If interim revisions are needed, the change criteria are listed in Table I, along with the responsibilities of the individuals.

Table I: Change, action and responsibilities

Type of Change and responsibility	Criteria and examples	Action
Moderate to major; involves RSO and may require notification to CNSC	<p><u>A change that could alter the conditions set in the license</u>, or that could potentially result in a higher dose</p> <ul style="list-style-type: none"> -Addition or removal of a room listed where radioactive work may be performed; -Addition or removal of a radioisotope from the list specified in the license; -A change in the radioisotope limit; -Use of radioisotopes in field work; -A change in personnel responsible of the management and control of nuclear substances. 	<ul style="list-style-type: none"> - Notification to RSO and/or review; - Notification and/or advice to CNSC.
Moderate; require involvement of RSO or License Holder	<p><u>A change within the limits and restrictions of the license</u>, not leading to a significant increase in radiological risk.</p> <ul style="list-style-type: none"> -New operation or procedure that requires a change in multiplication factor; -Disposal of radioactive material requiring transport to locations outside the university; 	<ul style="list-style-type: none"> - Keep a copy of the change in the laboratory log book; - Consult with License Holder and/or RSO.
Minor; License Holder or individual laboratory investigator	<p><u>A change with little or no safety significance.</u></p> <ul style="list-style-type: none"> -Disposal of radioactive material by approved routes for quantities below EQ; -Minor changes in laboratory procedures; -Add or delete names of authorized workers; -Updates on the training status of workers; -Relocation of radioisotopes between authorized laboratories for storage, for quantities below the inventory limit set in the license. 	<ul style="list-style-type: none"> - Keep a copy of the change in the laboratory log book; - Provide this information during license renewal or when required by RSO.

Note that the list of items is not exhaustive, and if in doubt, consult the RSO.

3. Authority and Responsibilities

3.1 University and Faculty level

3.1.1 The Manager, Health and Safety:

- Advises in matters of Health and Safety;
- Ensures that the RSP manual is consistent with other University safety Policies.

3.1.2 The Dean, Faculty of Science and Engineering:

- Provides administrative support for the licenses and the RSP (e.g., correspondence between Laurentian university and the CNSC);
- Is the final administrative authority in the operation of the licensed activities.

3.2. The Radiation Safety Officer (RSO):

- Reviews and helps licence applications and updates;
- Ensures that License Holders operate their laboratories according to the RSP;
- Provides technical support for calculations (dose rates, waste management, compliance, etc.), and advises the laboratory staff in radiation protection matters;
- Conducts assessments of work, on radiological safety matter, not covered in the RSP;
- Provides to the University and to external agencies information and reports on situations and activities involving radiation, as required;
- Provides general training to new users;
- Assumes control in emergencies involving radiation hazards and takes such actions as may be necessary to ensure the safety of personnel, property, and equipment, and reports these at the earliest possible time to University Authorities.
- Has the authority to shut down, temporarily or indefinitely, any process or laboratory that he/she considers to be in violation of University Safety Policies or CNSC regulations.
- Inspects and surveys laboratories and other workplaces where radioisotopes, or any other radiation emitting devices are used (exclusive of X-ray emitting devices);
- Advises the University Authorities and license holders on new Federal and Provincial legislation or items which may affect the use of radiation on campus;
- When asked by Purchasing, reviews the purchase orders of radioactive materials and other radiation sources, and checks these against issued permit;
- Keeps a duplicate inventory file of radioactive sources by permit (Note: it is the task of the individual License Holders to keep the inventory up-to-date and give a copy to the RSO);
- Keeps a duplicate list of the records of Health Canada personnel dosimeters.

3.3. The Associate RSO:

- Replaces the RSO in his/her absence, or as directed by the Dean;
- Acts as RSO in locations off the main Laurentian University campus (e.g. Elliot Lake Research Field Station)

3.4. The License Holders:

- Report contamination monitoring results as required (e.g., device or source leak tests);
- Prepare the licence application renewals, in consultation with the RSO and the Individual Investigators, as needed;

NOTE: In the case that a License is for a single device or Laboratory, the responsibilities of the License Holders and the Laboratory Supervisors are the same.

3.5 The Laboratory Supervisors:

- Ensure the safe conduct of operations in the Laboratory or devices, including the wearing of appropriate safety equipment, photobadges, etc.;
- Keep an up-to-date list of workers and their training;
- Provide support to the License Holder and/or the RSO in licence applications;
- Provide laboratory-specific training, and review specific procedures for compliance with this RSP and other safety measures;
- Report all radiation incidents involving radiation to the License Holder (to the RSO in case of a single Laboratory License);
- Keep an inventory of radioisotope holdings, acquisitions and dispositions, and ensuring that the possession limits are not exceeded. Update the License Holder when applicable;
- Authorize and review experiments in progress after normal working hours;
- Supervise and/or dispose of the wastes generated in his/her laboratory according to the policies set in this RSP, and takes care of the costs as a part of the research activities.
- Ensure that the Laboratory or Facility is secured against unauthorized access;
- Arrange for adequate facilities, equipment, etc., in compliance with this RSP. It is the responsibility of an Investigator to have adequate facilities, and to solicit the usual funding sources of research for improving the Facilities or equipment;
- Ensure that all workers have proper radiation training, including visitors. The Individual Investigator has the authority to disallow a worker from working with radiation if the worker does not perform satisfactorily, or if the worker does not provide sufficient proof of training.
- Posting of warning signs and labels as required by the CNSC or other safety councils.
- Ensure that photobadges are sent for reading on time, and at the end of a worker's term.

3.6 The Radioisotope Workers:

- Comply with this RSP and GLP guide;
- Comply with other laboratory-specific safety regulations not listed in this document;
- Report any radiological incident to the Laboratory Supervisor or License Holder (as applicable) as soon as reasonably possible after the event, consistent with University Policy;
- Properly label and store radiation sources, and to properly record and label the wastes;
- Keep the radioisotope inventory logbook up-to-date.

3.7 The Purchasing personnel:

- Keep a duplicate copy of the permits;
- Review the purchase orders of radioactive materials and other radiation sources, and confirm with the RSO that the quantities and radioisotopes are within the limits of the issued permit;

3.8 The Receiving personnel:

- Inspect parcels of radioactive shipments, upon receiving, for damage;
 - If damage is present and there is evidence of leak, do not accept shipment and consult the RSO prior to returning or moving the item, to avoid the spread of contamination;
- Safely handle and deliver the purchased radioisotopes to the authorized laboratories.

3.9 The Dosimetry coordinator:

- Keeps an inventory of photobadges in a safe place, away from radiation sources;
- Provides badges to authorized workers;
- Ships the badges collected from Workers or Laboratory Supervisors to dosimetry services;
- Receives and distributes the dosimetry results to the License Holders, and keeps a duplicate copy.

3.10. Delegation of Responsibility by permit holders or investigators

There may be circumstances where the Permit Holder or the Individual Investigator is absent from the laboratory for a prolonged time. Under this situation or similar circumstances, the responsibilities of the permit holder or Individual Investigator can be delegated to a qualified worker. Permission of the RSO must be obtained before the responsibilities can be delegated, and such responsibility is returned to the Permit Holder or Individual Investigator upon his/her return. Each request will be considered individually and a final decision will be made based on the technical ability and/or training history of the delegated worker.

For insurance purposes, a delegated person may not be someone from outside Laurentian University, such as a visitor or a contractor.

3.11 Users of X-ray Equipment

This RSP does not cover safety aspects related to the use of X-ray equipment.

4. General discussion of Radiological Hazards

4.1. Types of radiation

There are four major types of radiation from radioactive material:

Alpha radiation

Alpha radiation or particles consist of two protons and two neutrons (equivalent to a He nucleus). Alpha radiation is usually produced from the decay of heavy radioactive atoms, generally heavier than Lead. Because of its large mass and positive charge, alpha radiation is usually stopped by a small amount of material. For example, alpha particles travel through less than 1 mm of water, or a single piece of paper. Alpha radiation is not a significant external dose, but it can contribute to a significant internal dose. Thus, damage may take place upon ingestion or inhalation.

Beta radiation

Beta radiation or particles consist of a fast electron. Beta radiation is produced from the decay of certain radioactive materials, such as tritium, carbon-14, phosphorus-32, to name a few. Depending upon its energy, a beta particle can travel through different distances in materials: less than 1 mm in water for tritium, nearly 1 cm for phosphorus-32. Generally, Beta radiation is an internal hazard, and external doses are not generally significant.

Gamma radiation (including X-rays)

Gamma radiation consists of an electromagnetic wave (photons), like ordinary visible light, but with a high energy. Gamma rays are released from the rearrangement of nuclei following a spontaneous decay of radioactive material, such as cobalt-60. Gamma rays are highly penetrating, hence they are considered mostly as an external hazard. Similarly, X-rays have the same characteristics as gamma rays, but they are of lower energy than gamma rays, and they are produced differently. They are also considered as an external hazard.

Neutrons

Fast neutrons are released from nuclear fission of heavy elements. Neutrons hardly damage cells because they do not carry any electrical charge, but since the human body contains a large amount of hydrogen (from water), the latter can become ionized when hit by neutrons. Neutrons are considered as external hazards. Neutrons are not generally generated in typical laboratories, thus this type of hazard is not likely at Laurentian University.

4.2 Internal Radiological Hazard

Internal radiological hazard is the potential dose that can result from an intake of a radioisotope (mostly from an alpha- or beta-emitting radioisotope) through a person's exposure to airborne or surface contamination. Alpha-emitting isotopes are much more hazardous per unit activity, compared to beta emitters. Assuming that laboratory staff follow the standard practices and procedures given in this protocol, significant intakes of radioactivity, and thus internal exposures, are unlikely to occur since all active work should only be done inside ventilated fumehoods. The amount of unsealed radioactive material in the laboratory is controlled and limited to low levels, and if the guide for handling radioactive materials is followed (Appendix G), only small exposures would result, if any.

Other precautions include, but are not limited to:

- Avoid the generation of dust, such as handling contaminated soils. Wetting soils with water could be a better practice;
- Use glove boxes when generation of radioactive dust or vapors is necessary;
- Keep good hygiene practices and avoid touching the eyes, nose, mouth, etc., while working;
- Eating or drinking is not allowed in the laboratory. The worker should step outside to take a break instead (remove gloves, remove lab coat, wash hands before drinking or eating);
- Clean up spills as soon as possible to avoid potential contamination;
- Check regularly for loose contamination with swipe tests and SVM (see Appendix I).

4.3 External Radiological Hazard

External radiological hazard is the potential dose that can result from exposure to a radiation field from gamma- or, less often, beta- or neutron-emitting radioisotopes through a person's exposure to a source of radioactivity outside the body.

General protection principles consist of:

- Time
 - handling gamma sources for a short time help keep a low absorbed external dose;
- Distance
 - handling gamma sources far from the body, or using instruments (tongs, forceps, etc.) will help decrease the dose absorbed;
- Shielding
 - the use of lead (for gamma emitters) or Plexiglas (beta emitters) will cut the external radiation by a large factor;
 - external dose from beta sources can be decreased by common material (glass containers of sources, air, plastic bags, etc.).

4.4 Units

The fundamental unit of radiation is a Becquerel (Bq), defined as one disintegration per second. The old unit (Curie, Ci) is equivalent to 3.7×10^{10} Bq (see conversion units in Appendix B).

Instruments measure radiation in counts per minute (cpm) or counts per second (cps), which corresponds to the number of disintegrations detected by an instrument. The general relationship is:

$$\text{Activity (Bq)} = \text{Signal detected by Instrument (cps)} \div \text{Instrument Efficiency (fractional)}$$

The instrument efficiency depends upon several factors, which are not discussed here.

The units of absorbed dose are in Grays (Gy). One Gray corresponds to one joule of energy from ionizing radiation deposited per kilogram of material. The old unit, the Rad, corresponds to 0.01 Gy (see conversion factors in Appendix B).

The units of dose in biological systems such as humans are in Sieverts (Sv). The old unit, the Rem, corresponds to 0.01 Sv (see conversion factors in Appendix B).

In biological systems such as humans, biological damage depends upon the amount of energy deposited per unit mass, and also how this energy is deposited within the mass. The particles that will produce most biological damage, such as alpha particles, will deposit their energy in a denser track than a gamma radiation. The gamma particles, which are more penetrating, will leave just a portion of their energy in their track. To account for this, the absorbed dose (Gy) is multiplied by a Qualifying Factor (QF) to give the biological effects in dose units (Sv). For example, the QF for most common radiations (gammas, X-rays, betas) is 1, where it can range up to 20 for some alpha particles.

There is no clear relationship between the activity units (Bq) and dose units (Sv), because it depends upon several factors.

4.5 Natural and man-made radiation

Radioactivity is a natural phenomenon. As shown in the table (next page), for general members of the population from the United States, most of the expected dose (82%) is from natural sources of radiation, of which most of it is from radon. Of the other 18%, the majority is from medical diagnosis and treatments, with <1% from nuclear power and fallout.

In Canada, the additional radiation doses due to emissions from CANDU power reactors ranged from 1.1 to 6.4 microSieverts (μSv) in 2001, for the most exposed persons living near a station. These radiation doses are calculated from actual data, obtained from routine analysis of air, water, fish, vegetation and station emission data.

4.6 Allowable dose

The total external dose allowed is 1 mSv per year (for non – Nuclear Energy Workers - NEW). This allowable dose is in the range of natural radiation (see Table II).

Table II: Annual estimated average effective dose equivalent received by a member of the population of the United States.

Source	Average annual effective dose equivalent	
	(μSv)	%
Inhaled (Radon and Decay Products)	2000	55
Other Internally Deposited Radionuclides	390	11
Terrestrial Radiation	280	8
Cosmic Radiation and cosmogenic radioactivity	280	8
Total from natural sources	3000	82
Total from artificial Sources (medical diagnostic and treatments, consumer products, fallout, nuclear reactors, etc)	600	18
Total	3600	100

Source: The Radiation Information Network, Radioactivity in Nature (www.physics.isu.edu/radinf/index.html).

5. Conduct of Operations

5.1 License management

The overall management of the license is the responsibility of the RSO, the License holder, and the Laboratory Manager, as outlined in Sections 3.3 to 3.5. Periodic inspections are required by law and must be reported in the Annual Compliance Report.

5.1.1 Obtaining an internal license

Laurentian University currently has 4 separate licenses (see section 2.2.1). If new work involving Nuclear Substances is required, the Investigator must contact the RSO to determine the category of the work, by providing the appropriate information:

1. User information, and prior training (if applicable);
2. Information on Radioisotope(s) to be used;
3. Description of work and laboratory settings, including safety features;
4. Plans for waste management;
5. Other miscellaneous information pertinent to safety.

Upon successful request, the location specified in the Application must conform to the current Policies at all times when Nuclear Substances are in the location.

5.1.2 Temporary licenses

The RSO, upon the request, may grant a Laboratory Supervisor a temporary license to use Nuclear Substances in a specific location. This Temporary License will be valid for 6 months, and may be renewed. During this time, it is the responsibility of the Laboratory Supervisor to ensure that the Location is compliant with all regulations, including posting the appropriate signs. After the period, it is the responsibility of the Laboratory Supervisor to contact the RSO to decommission the Laboratory.

5.1.3 Change in Status

The RSO, upon regular inspection, may request a change in status from “Active Laboratory” to “Inactive Laboratory”, if no work with Nuclear Substances has been performed within a location for 6 months, or if no such work will be planned within 6 months, or as judged necessary. The Laboratory must be decommissioned to return to its inactive status.

An inactive laboratory which was previously classified as “Active” can be re-instated upon request by the Laboratory Manager. The information listed above (section 5.1.1) will be requested.

5.1.4 Routine inspections

As a part of our license requirements, self-audits have to be performed on a regular basis. The audit will consist of verification of items usually covered in CNSC inspections (Appendix L), and whether the Laboratory should retain its “Active” status.

5.2 Training

Any Laboratory worker expected to work with radiation at Laurentian University will be required to take a two-stage training. The first stage consists of the theory of radioactivity and radioprotection. This module is general and it applies to all situations. The second stage of training is laboratory-specific, and is given by the Laboratory supervisor. The Laboratory Supervisor shall keep an up-to-date list of the trainees and give a copy of this list to the license holder.

The Laboratory Supervisor will ensure that all personnel working with radiation have a current copy of the current RSP and are familiar and knowledgeable with its contents.

Other staff regularly entering the premises, such as cleaning staff or Security, should have a minimum informative training.

5.2.1 Radiation Protection Training

Authorized Laboratory workers and the Laboratory Supervisor must successfully take a minimum theoretical training, which covers the subjects listed under “Laboratory Technician” and “Research Students”, in the proposed Regulatory Guide C-200. This training must be provided by a RSO whose professional qualification includes formal training on the matter.

5.2.2 Laboratory-specific Radioisotope Protocol Training

The content of the Laboratory-specific training is left to the discretion of the Laboratory Supervisor. It is recommended that the other personnel in the same laboratory, but not working with radiation, should have informative training similar to support/janitorial staff, and to be familiar with emergency procedures.

5.2.3 Support staff and janitorial training

Support staff, such as security personnel, janitors, shipping and receiving personnel, and other maintenance people should have informative training, covering mostly procedures, as outlined in document C-200 [7]. In addition to this, personnel responsible of receiving and shipping radioactive material should have training on Dangerous and Hazardous material handling.

5.3 Inventory Limits and Inventory Control

The radionuclide inventory will be controlled by the use of a logbook. Materials entering and leaving the laboratory (including waste) are controlled by the Laboratory Supervisor, and will be recorded in the logbook by the Laboratory workers. All transfers between authorized

laboratories must be recorded in both logbooks, i.e., the laboratory where the material came from, and the destination laboratory. The destination room must be listed in the license, along with the radioisotope, but the individual limit must not be exceeded. This should be noted for the annual report of the license holder activities. This does not apply for quantities below the EQ, but it is recommended, however, that this practice be used (because several samples or aliquots below EQ can boost the inventory above EQ).

Examples of information required in the log book are in Appendix J of this Guide.

5.4 Posting of signs

5.4.1 The Radiation Warning Symbol

The Radiation Warning Symbol consists of a trefoil, color black or magenta, on a yellow background. The words "RAYONNEMENT -- DANGER -- RADIATION" must also be placed prominently on the sign, with an area available to show the quantity and the form of nuclear substances.

Examples of signs are in Appendix K of this document. Contact the RSO to obtain electronic copies of the sign, or the indications in [6] can be used to make one.

Whenever the Radiation Warning Symbol is used, it shall be:

- prominently displayed;
- sized appropriately for the container or device to which it is affixed or attached, and similarly for an area, room, enclosure or vehicle, and;
- no wording shall be superimposed on it.

5.4.2 Frivolous Posting of Signs

No Radiation Warning Sign shall be posted if the nuclear substance or prescribed equipment indicated on the sign is not present.

5.4.3 Posting of signs on devices or containers

Any container or device (i.e., instrument) containing a radioactive nuclear substance must have a Radiation Warning Sign, plus the name, quantity, date of measurement and form of the nuclear substance in the container or device.

Exceptions to this rule are:

- containers or devices containing less than the exemption quantity (EQ) of nuclear substance;
- containers or devices used to hold nuclear substances for current or immediate use, under the continuous and direct observation of the licensee;

- containers or devices used exclusively for transporting radioactive nuclear substances, and labelled in accordance with the *Packaging and Transport of Nuclear Substances Regulations*.

5.4.4 Posting of Signs at Boundaries and Points of Access

A durable and legible sign must be posted at the boundary of, and at every access point of an area (room, vehicle, enclosure, etc) if:

- there is a nuclear substance in a quantity greater than 100 times its EQ in the area, room, enclosure or vehicle, except in respect of a vehicle that is placarded in accordance with the *Packaging and Transport of Nuclear Substances Regulations*; or
- there is a reasonable probability that a person in the area, room, enclosure or vehicle will be exposed to an effective dose rate greater than 25 $\mu\text{Sv/h}$.

5.5 Access and control of Nuclear Substances

All Radioactive and Nuclear Substances shall be under the direct supervision of authorized workers, or shall be locked and not accessible when not supervised. Keys or lock combinations shall not be shared with unauthorized personnel.

The laboratory supervisor or designate is the only person who can authorize access to nuclear materials.

The Laboratory supervisor can authorize special experiments with nuclear materials that can be run overnight, provided that the quantities are low, spills can be contained, and that access is restricted to authorized personnel (including other students, laboratory users, janitorial and security staff). These experiments must be planned and the procedures (operating and emergency) shall be prepared ahead of time and approved by the laboratory supervisor.

5.6 Leak testing of sources

Sealed sources, which consist of radioactive material sealed in a capsule or having a bonded cover, strong enough to prevent contact or dispersion of radioactive material, should be tested for leaks on a frequent basis, as a measure to minimize the spread of contamination. This applies only to sources above 50 MBq. The frequency of leaks tests depends upon the utilization of the sources, and it is up to the Laboratory Supervisor to decide on the frequency. Records should be kept in the laboratory logbook for a minimum of 3 years, and be available upon request.

Leak testing consist, in short, of the following (Consult guide R-116 [9] for more details):

- a list of devices sampled, and their location;
- a step-by-step procedure for the wipe sampling;
- a description of the types of wipe samples;
- an example of completed leak tests;

- the meter used should be able to detect 200 Bq or less.

The procedure must be approved by the CNSC, or it must be done by an agency/licensee whose procedure is approved by the CNSC. Consult the RSO if such measurements are necessary.

5.7 Modifying factors

In situations where the state of radionuclide samples above EQ (considered as radioactive work) or below EQ (non-radioactive work) is modified, there is potential for contamination or increased exposure. For this purpose, modifying factors are used to alter (positively or negatively) the quantity of radionuclides that can be used at one time. Determination of the correct modifying factor for planned operations depends on the likelihood of radioactive contamination during routine and upset conditions. Specific factors to consider include:

- a) complexity of work;
- b) physical form of radioactive materials (e.g., solid, liquid, powder, gas);
- c) volatility and chemical properties of radioactive materials;
- d) concentrations of radioactivity;
- e) potential for generating airborne gases, vapors or aerosols;
- f) particular aspects of the procedure or process that could give rise to airborne or loose contamination during routine and upset conditions;
- g) any other factor susceptible of increasing the risk of contamination.

The modifying factors are important especially if/when:

- the quantity of radionuclide used is near the laboratory limit;
- the quantity of radionuclide is below the EQ limit, but could become above this level, and hence would be considered as radioactive work.

The assignment of a modifying factor will rely, in part, on qualitative judgment and individual experience. For example, normal chemical operations can be carried out with up to 37 MBq of a Group 2 radionuclide (High radiotoxicity) in a Basic Level laboratory. If the work consisted of grinding the material in dry state, hence with the potential volatilization of this radionuclide, only 0.37 MBq (i.e., 37 MBq \times modifying factor 0.01 – see Appendix E) should be handled unless additional precautions are taken against dust generation.

If two or more radionuclides or mixtures of radionuclides are handled, and/or there are multiple types of operations in a laboratory, the activity limits are calculated considering that each radionuclide and operation are done separately. The sum of all values should be used. Consult the RSO for assistance in the matter.

5.8 Work Control

All work in this laboratory is supervised and approved by the Laboratory Supervisor. All authorized users should have a thorough knowledge and understanding of this RSP, and work

within its scope. All work with radioisotopes should be documented in procedures and reviewed by the Laboratory supervisor prior to working.

Laboratory Users not listed in the users list (“Unlisted”) who need to perform short-term work in this laboratory must first receive approval from the Laboratory Supervisor, and his/her work must also be approved in advance by the Laboratory Supervisor. Depending on the nature/scope of the work, approval may require the submission, by the “unlisted” worker, of a detailed experiment proposal or plan to compensate for the lack of training.

The Laboratory Supervisor is responsible for establishing and approving the qualifications of staff to work in his/her laboratory.

Service personnel require permission from the Laboratory Supervisor to perform non-routine maintenance work in the laboratory. Routine work (cleaning, replacing light bulbs, etc.) by support staff is permitted, as per the description of section 5.1 above.

5.9 Standard Practices, GLP and ALARA

Working experience shows that there are generally accepted rules and good practices for the safe handling of radioactive materials, and the operation of radioisotope laboratories. The general principles rely on:

- Commitment of the Laboratory and University to safety;
- Training of workers;
- Low inventory of radioisotopes;
- Good Laboratory Practices.

Some Good Laboratory Practices (GLP) are listed in Appendix G for convenience. The items listed in appendix are consistent with the regulatory document G-129 [10] to ensure that radiation exposure follows the ALARA principle (As Low As Reasonably Achievable). Additional laboratory-specific practices deemed reasonable can also reduce the radiological risk.

5.10 Use of Radiation Protection Instruments

Laboratory Users are permitted to operate the portable radiation survey instruments, for which they have received training, only for the purposes of performing self-verification measurements (SVM). Each worker is responsible of finding an appropriate radiation monitor while performing radiation work. Contact the RSO for a list of available portable meters.

Survey meters should be calibrated annually, either by their individual owners using the Regulatory Guide R-117 [11], or by sending meters to a certified calibration service.

5.11 Movement of Sources, Materials, and Equipment

The following requirements from the above procedures are important to note:

- All containers with radioactive materials shall be appropriately labeled. Quantities below EQ should not be labelled as “radioactive” with the trefoil sign. It is illegal to place a “radioactive” sign on non-radioactive material.
- All radioactive materials (i.e., above EQ) entering or leaving a laboratory, must be approved by the Laboratory supervisor with prior discussion.
- Measuring equipment containing sources must not be moved from their locations unless there is a prior written consent, as this will alter the conditions of the license.

5.12 Contamination control and decommissioning

In addition to being familiar with GLPs, authorized workers are asked to perform Self-Verification Measurements (SVM) on a daily or weekly basis, depending upon the frequency of the work (see procedure in Appendix I). Spread of loose contamination should be kept to a minimum, while fixed contamination can be present at low levels for controlled areas. Upon decommissioning, contamination levels should be kept as low as possible. The following is a guide for acceptable levels of contaminations (based on ref. [7]):

For controlled areas:

- 3 Bq/cm² of Class A radionuclides (Groups 1 and 2 in Appendix F), which are long-lived and emit alpha radiation, and can contain high energy gamma emitters.
- 30 Bq/cm² of Class B radionuclides (Group 3 in Appendix F), which are long-lived and emit beta or gamma radiation.
- 300 Bq/cm² of Class C radionuclides (Group 4 in Appendix F), which are short-lived and emit beta or gamma radiation.

For supervised public areas and for decommissioning:

- 0.3 Bq/cm² of Class A radionuclides (Groups 1 and 2 in Appendix F);
- 3 Bq/cm² of Class B radionuclides (Group 3 in Appendix F);
- 30 Bq/cm² of Class C radionuclides (Group 4 in Appendix F).

Monitoring for radioactive contamination can be done by indirect or direct methods:

- The indirect method consists of collecting a wipe sample from workplace surfaces (usually covering 100 cm²), followed by measurement with a ratemeter (loose contamination);
- The direct method involves using a portable instrument to measure contamination directly on surfaces (loose and fixed contamination). This method is preferred to determine fixed contamination after the surface has been cleaned (i.e., removal of loose contamination).

In both cases, the measurement must be compared to a low-level radiation surface to obtain the background. The result reported for the contaminated surface should be the net count, i.e., “contaminated surface” – “background” = net counts.

5.13 Waste Management

Active wastes should be disposed of in accordance to the Regulatory Quantities listed in Appendix D of this RSP. The quantity disposed of must be recorded in the log book, for mass balance purposes. Accepted waste management practices are:

- Storage and decay;
- Disposal through municipal or chemical waste management systems, provided that the quantities are below Regulatory Quantities:
 - solid wastes (up to 3 tons/year per licensed address);
 - municipal sewer, provided that the wastes are water-soluble;
 - atmospheric releases;
 - companies specialized in the management of toxic/chemical wastes;
- Transfer to another licensee;
- Transfer/return to supplier
- Disposition and shipment to approved nuclear waste management facilities.

Note that dilution is not considered to be an acceptable waste management practice unless it is part of an approved procedure.

A record of waste disposition through any of the above must be kept for mass balance purposes. Disposition other than storage and decay require written approval by the RSO.

5.14 Dosimetry

Routine external radiation dosimetry for Laboratory Users is usually measured with a personal photobadge. In exceptional situations, the RSO may recommend additional special dosimetry instruments, such as additional badges, extremity TLD's etc., or internal dosimetry, such as bioassays (urine or fecal samples). If intake has taken place, the Laboratory Supervisor is responsible for ensuring that the follow-up monitoring is performed, and for ensuring that appropriate actions are taken to determine the cause of the intake.

Personnel working with radioisotopes are not required to wear photobadges if there is a reasonable probability that doses do not exceed 5 mSv per year [12]. In general, extremity TLD's must be worn if handling more than 50 MBq sources at a time. When personnel are required to wear photobadges, the latter must be worn in a place that will take a representative measurement of the doses, such as on the trunk of the body, or inside the fingers (extremity TLD's). Photobadges must be stored away from radiation sources while not working (e.g., overnight). It is also the responsibility of the workers to hand back the photobadges at the time the latter are to be read for dosimetry purposes (on a quarterly basis). The Laboratory supervisors and/or license holders should enforce this policy.

5.15 Assistance from RSO

The RSO is responsible for providing advice to help reduce personnel radiation exposures and to minimize contamination spread within, and from the laboratory. The RSO will also perform routine radiation and contamination monitoring in the laboratory as part of his/her routine duties, and when specifically requested by Laboratory Supervisors.

Laboratory Supervisors/users are expected to call the RSO for items or issues that are beyond their training:

- When samples, or the way that the samples must be handled, are unusual and can result in contamination or radiation exposure (i.e., see multiplication factors);
- For advice with respect to reduction of personnel radiation exposures;
- Whenever they are concerned about potential exposure or contamination spread during handling, storage or transfer of radioactive materials (if not covered in the training);
- In the event of a spill or upset outside the containment area.

5.16 Transport and packaging

On-site transport at Laurentian University, from Receiving to the individual Laboratories, requires that the personnel are trained for the Transport of Dangerous Goods (TDG) and informative training (see Section 5.2.3 of this guide).

Off-site transport and packaging is an infrequent occurrence at Laurentian University. Regulations from both the CNSC (*Packaging and Transport of Nuclear Substances Regulations* [13]) and Transport Canada (*Transport of Dangerous Goods* [14]) must be met. Acquisition and off-site shipment of Nuclear Substances is permitted only between permit holders, with prior written approval.

The RSO must approve in writing the transport of nuclear material off-site (receiving and shipping).

(intentionally left blank)

6. References

- [1] Health and Safety Policies and Procedures, Laurentian University, September 2000.
- [2] Laboratory Safety Handbook, Laurentian University, February 1997.
- [3] Health Physics Manual, McMaster University, Hamilton, ON (1987).
- [4] Radiation Safety Policy and Procedures, Queen's University at Kingston (1998). [Web version, accessed 2002 February]. <http://www.safety.queensu.ca/safety/radiation/manual/>
- [5] F. Caron, Radioisotope laboratory protocol for Emissions Management Technologies Branch Laboratory. Chalk River Laboratories, Chalk River, ON (1999) [Unpublished].
- [6] Radiation Protection Regulations. Nuclear Safety and Control Act, Government of Canada (N-28.3 – SOR/2000-203), updated to April 30, 2001 (<http://laws.justice.gc.ca/en/N-28.3>).
- [7] Unsealed Nuclear Substances, C-141 Rev 1 (E) License application form and guide, Canadian Nuclear Safety Commission, Aug. 15, 2000.
- [8] Radiation Safety Training for radioisotope, medical, accelerator and transportation workers. Proposed regulatory guide, Atomic Energy Control Board of Canada, document C-200 (1998).
- [9] Requirements for leak testing selected sealed radiation sources. Regulatory Document, Atomic Energy Control Board of Canada, Document R-116 (1995).
- [10] Guidelines on how to meet the requirement to keep all exposures as low as reasonably achievable. Regulatory guide, Atomic Energy Control Board of Canada, document G-129 (1997).
- [10] Requirements for gamma radiation survey meter calibration. Regulatory Document, Atomic Energy Control Board of Canada, Document R-117 (1995).
- [11] Radioisotope release concentrations. Proposed Policy statement, Atomic Energy Control Board of Canada, document C-123 (1995).
- [12] Ascertaining and recording radiation doses to individuals. Draft regulatory guide, Canadian Nuclear Safety Commission, document C-091 (2001).
- [13] Packaging and Transport of Nuclear Substances Regulations. Nuclear Safety and Control Act, Government of Canada (SOR/2000-208), May 31, 2000 (2000).
- [14] Transportation of Dangerous Goods Act, 1992a, Canada Gazette, Part I (SOR/2001-286), August 7, 1999 (2001).

APPENDICES

APPENDIX A:

RADIATION DOSE LIMITS

(modified from [6]).

Annual Limit on Intake

The "ALI" or "annual limit on intake" means 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.

Effective Dose Limits

Every licensee shall ensure that the effective dose received by, and committed to a person described the first column of the table below, during the period set out in the second column of that item, does not exceed the effective dose set out in the third column of that item.

The applicable dose limit for workers at Laurentian University shall be the third item of this column – non-NEW. Under exceptional circumstances a person may ask to become a NEW. The RSO must be contacted to review the reasons and the need for the change in classification.

TABLE A-1: Radiation dose limits.

Item	Period	Effective Dose (mSv)
1. Nuclear energy worker (NEW*), including a pregnant nuclear energy worker	(a) One-year dosimetry period	50
	(b) Five-year dosimetry period	100
2. Pregnant nuclear energy worker	Balance of the pregnancy	4
3. A person who is not a nuclear energy worker (non-NEW)	One calendar year	1

*Formerly Atomic Radiation Worker – ARW.

APPENDIX B:

MEASUREMENT UNITS CONVERSION TABLE

Systeme International (SI) Units

1 Gray	=	1 joule of ionising radiation per kilogram of material
1 Sievert	=	1 Gray × qualifying factor (qualifying factors depend upon the type of radiation and the part of a human body receiving a radiation dose)
1 Becquerel	=	1 radioactive disintegration per second

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)

The gray (Gy) replaces the rad (rad)

1 gray (Gy)	=	100 rad (rad)
1 milligray (mGy)	=	100 millirad (mrad)
1 microgray (μGy)	=	100 microrad (μrad)

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)

The sievert (Sv) replaces the rem (rem)

1 sievert (Sv)	=	100 rem (rem)
1 millisievert (mSv)	=	100 millirem (mrem)
1 microsievert (μSv)	=	100 microrem (μrem)

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

1 curie (Ci)	=	37 gigabecquerels (GBq)
1 millicurie (mCi)	=	37 megabecquerels (MBq)
1 microcurie (μCi)	=	37 kilobecquerels (kBq)

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

1 gigabecquerel (GBq)	=	27 millicuries (mCi)
1 megabecquerel (MBq)	=	27 microcuries (μCi)
1 kilobecquerel (kBq)	=	27 nanocuries (nCi)

APPENDIX C:

CLASSIFICATION OF LABORATORIES OR WORKING PLACES

Source: C-141 guide [7]

Radionuclide	Radiotoxicity	Annual Limit of Intake - estimate (ingestion) MBq/yr	Basic level MBq	Intermediate level MBq	High level MBq
Br-82	H	37	185	1850	18500
C-14	M	34	170	1700	17000
Co-57	M	95	475	4750	47500
Co-58	M	27	135	1350	13500
Co-60	H	6	30	300	3000
Cr-51	M	530	2650	26500	265000
F-18	M	400	2000	20000	200000
Fe-59	M	10	50	500	5000
Ga-67	M	100	500	5000	50000
H-3	L	1000	5000	50000	500000
I-123	M	95	475	4750	47500
I-125	H	1	5	50	500
I-131	H	1	5	50	500
In-111	M	70	350	3500	35000
Na-22	H	6	30	300	3000
P-32	H	8	40	400	4000
P-33	M	80	400	4000	40000
Ra-226	VH	0.07	0.35	3.5	35
S-35	M	26	130	1300	13000
Sb-124	H	8	40	400	4000
Sr-85	M	36	180	1800	18000
Tc-99m	L	900	4500	45000	450000
Tl-201	M	210	1050	10500	105000
Xe-133	L				

APPENDIX D:

REGULATORY QUANTITIES FOR TYPICAL RADIONUCLIDES

Source: C-141 guide [7]

Radionuclide	EQ MBq	Wipes Controlled area Bq/cm ²	Wipes Public area Bq/cm ²	Garbage MBq/kg	Sewer MBq/yr	Air kBq/m ³
Br-82	0.1	30	3			
C-14	100	300	30	3.7	10000	
Co-57	0.1	300	30	0.37	1000	
Co-58	0.1	30	3	0.37	100	
Co-60	0.1	3	0.3	0.01	0.1	
Cr-51	1	300	30	3.7	100	
F-18	0.01	30	3	0.01		
Fe-59	0.1	30	3	0.01	1	
Ga-67	1	30	3	0.037	100	
H-3	1000	300	30	37	1000000	37
I-123	10	300	30	3.7	1000	3
I-125	1	300	30	0.037	100	0.03
I-131	0.01	30	3	0.037	10	0.175
In-111	0.1	30	3	0.037	100	
Na-22	0.01	3	0.3	0.01	0.1	
P-32	0.01	300	30	0.37	1	
P-33	1	300	30	1	10	
Ra-226	0.01	3	0.3	0.01	1	
S-35	100	300	30	0.37	1000	
Sb-124	0.01	3	0.3	0.37		
Sr-85	0.1	30	3	0.37	10	0.175
Tc-99m	10	300	30	3.7	1000	
Tl-201	1	300	30	0.037	100	
Xe-133	100000					

For the radioisotopes not mentioned above:

Radiotoxicity	Basic level MBq	Intermediate level MBq	High level MBq
Very High (Group 1) VH	0.37	3.7	37
High (Group 2) H	37	370	3700
Moderate (Group 3) M	370	3700	37000
Low (Group 4) L	3700	37000	370000

APPENDIX E:
MODIFYING FACTORS

Modifying factors are applicable to the quantities shown in the last three columns according to the types of operation and complexity of the procedures to be followed. The following factors are recommendations. However, due regard should be paid to the circumstances affecting individual cases.

Type of Operation	Modifying Factor
Storage of unsealed sources.	× 100
Very simple, uncomplicated handling of liquids. Potential for spills or generating loose surface or airborne contamination is very low.	× 10
Normal chemical operation. Potential for spills or generating surface or airborne contamination is low or moderate.	× 1
Complex wet and simple dry operation. Complicated handling of liquids where there is a danger of splashing or vaporization, as well as uncomplicated handling of dry matter, and animal experiments.	× 0.1
Dry and dusty operation. Handling of dry matter with a danger of dust formation.	× 0.01

APPENDIX F:
RADIOTOXICITY OF RADIONUCLIDES

(Based on references [4 - 6])

Group 1. Very High Radiotoxicity

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

Group 2. High Radiotoxicity

Actinium 228	(6.1 hours)	Lead 212	(10.6 hours)
Antimony 124	(60 days)	Manganese 54	(314 days)
Antimony 125	(2.7 years)	Protactinium 230	(17 days)
Astatine 211	(7.2 hours)	Radium 224	(3.6 days)
Barium 140	(12.8 days)	Ruthenium 106	(1.0 years)
Berkelium 249	(314 days)	Scandium 46	(84 days)
Bismuth 207	(30 years)	Silver 110m	(249 days)
Bismuth 210	(5.0 days)	Sodium 22	(2.6 years)
Cadmium 115m	(43 days)	Strontium 89	(50 days)
Calcium 45	(165 days)	Strontium 90	(28 years)
Cerium 144	(285 days)	Tantalum 182	(115 days)
Cesium 134	(2.1 years)	Tellurium 127m	(105 days)
Cesium 137	(30 years)	Tellurium 129m	(33 days)
Chlorine 36	(3×10^5 years)	Terbium 160	(73 days)
Cobalt 56	(77 days)	Thorium 234	(24.1 days)
Cobalt 60	(5.3 years)	Thulium 170	(127 days)
Europium 152	(13 years)	Uranium 236	(2.4×10^7 years)
Europium 154	(16 years)	Yttrium 91	(59 days)
Hafnium 181	(45 days)	Zirconium 95	(65 days)
Indium 114m	(50 days)	Thallium 204	(3.8 years)
Iodine 124	(4.2 days)	Thulium 170	(127 days)
Iodine 125	(57 days)	Uranium 236	(2.4×10^7 years)
Iodine 126	(132.2 days)	Yttrium 91	(59 days)
Iodine 131	(8.0 days)	Zirconium 95	(65 days)
Iodine 133	(21 hours)	Thallium 204	(3.8 years)
Iridium 192	(74 days)		

Group 3. Moderate Radiotoxicity

Antimony 122	(2.8 days)	Iodine 130	(12.5 hours)
Argon 41	(1.8 hours)	Iodine 132	(2.3 hours)
Arsenic 73	(76 days)	Iodine 134	(53 minutes)
Arsenic 74	(18 days)	Iodine 135	(6.7 hours)
Arsenic 76	(26.5 hours)	Iridium 190	(12 days)
Arsenic 77	(39 hours)	Iridium 194	(19 hours)
Barium 131	(11.6 days)	Iron 52	(8.3 hours)
Beryllium 7	(53 days)	Iron 55	(2.7 years)
Bismuth 206	(6.2 days)	Iron 59	(45 days)
Bismuth 212	(60.6 minutes)	Krypton 85m	(4.4 hours)
Cadmium 109	(1.3 years)	Krypton 87	(78 minutes)
Cadmium 115	(2.3 days)	Lanthanum 140	(40.2 hours)
Calcium 47	(4.5 days)	Lead 203	(52 hours)
Carbon 14	(5730 years)	Lutetium 177	(6.8 days)
Gerium 141	(32.5 days)	Manganese 52	(5.7 days)
Cerium 143	(33 hours)	Manganese 56	(2.6 hours)
Cesium 131	(9.7 days)	Mercury 197m	(24 hours)
Cesium 136	(13 days)	Mercury 197	(65 hours)
Chlorine 38	(37 minutes)	Mercury 203	(47 days)
Chromium 51	(27.8 days)	Molybdenum 99	(66 hours)
Cobalt 57	(267 days)	Meodymium 147	(11.1 days)
Cobalt 58	(71 days)	Neodymium 149	(1.8 hours)
Copper 64	(12.9 hours)	Neptunium 239	(2.4 days)
Dysprosium 165	(2.3 hours)	Nickel 63	(92 years)
Dysprosium 166	(80 hours)	Nickel 65	(2.6 hours)
Erbium 169	(9.4 days)	Niobium 93m	(3.7 years)
Erbium 171	(7.5 hours)	Niobium 95	(35 days)
Europium 152m	(9.2 hours)	Osmium 185	(94 days)
Europium 155	(1.7 years)	Osmium 191	(15 hours)
Fluorine 18	(111 minutes)	Osmium 193	(32 hours)
Gadolinium 153	(200 days)	Palladium 103	(17 days)
Gadolinium 195	(18 hours)	Palladium 109	(13.5 hours)
Gallium 72	(14.1 hours)	Phosphorus 32	(14.3 days)
Gold 196	(6.2 days)	Phosphorus 33	(25.3 days)
Gold 198	(64.8 hours)	Platinum 191	(3.0 days)
Gold 199	(3.15 days)	Platinum 193	(500 years)
Holmium 166	(9x104 years)	Platinum 197	(2.0 hours)
Indium 115m	(4.4 hours)	Potassium 42	(12.4 hours)

Group 3. Moderate Radiotoxicity

(cont'd)

Potassium 43	(22 hours)	Technetium 96	(43 days)
Praseodymium 142	(19.2 hours)	Technetium 97m	(91 days)
Praseodymium 143	(13.7 days)	Technetium 97	(2.6×10^6 years)
Promethium 147	(2.5 years)	Technetium 99	(2.1×10^5 years)
Promethium 149	(53 hours)	Tellurium 125m	(58 days)
Protactinium 233	(27.4 days)	Tellurium 127	(9.3 hours)
Radon 220	(56 seconds)	Tellurium 129	(67 minutes)
Radon 222	(3.8 days)	Tellurium 131m	(1.2 days)
Rhenium 183	(70 days)	Tellurium 132	(78 hours)
Rhenium 186	(90 hours)	Thallium 200	(26 hours)
Rhenium 188	(17 hours)	Thallium 201	(73 hours)
Rhodium 105	(36 hours)	Thallium 202	(12 days)
Rubidium 86	(18.7 days)	Thorium 231	(25.6 hours)
Ruthenium 97	(2.9 days)	Thulium 171	(1.9 years)
Ruthenium 103	(40 days)	Tin 113	(118 days)
Ruthenium 105	(4.4 hours)	Tin 125	(9.4 days)
Samarium 151	(90 years)	Tungsten 181	(130 days)
Samarium 153	(46.7 hours)	Tungsten 185	(74 days)
Scandium 47	(3.4 days)	Tungsten 187	(24 hours)
Scandium 48	(44 hours)	Vanadium 48	(16.1 days)
Selenium 75	(120 days)	Xenon 135	(9.2 hours)
Silicon 31	(2.6 hours)	Ytterbium 175	(4.2 days)
Silver 105	(40 days)	Yttrium 90	(64.2 hours)
Silver 111	(7.5 days)	Yttrium 92	(3.5 hours)
Sodium 24	(15 hours)	Yttrium 93	(10.1 hours)
Strontium 85	(64 days)	Zinc 65	(245 days)
Strontium 91	(9.7 hours)	Zinc 69m	(14 hours)
Sulfur 35	(87 days)	Zirconium 97	(17 hours)

Group 4. Slight or Low Radiotoxicity

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

APPENDIX G:
GUIDE TO GOOD LABORATORY PRACTICES (GLP)

(modified from ref. [5])

This list is a partial compilation of good practices for the safe handling of radioisotopes taken from various sources. This list is not meant to be exhaustive and additional good practices that could be applicable to specific laboratories.

Laboratory Users must follow good practices when working with radioactive materials. Each individual Laboratory Supervisor is responsible for enforcing good practices in their laboratory.

GENERAL

1. Ensure that all personnel handling radiation sources are trained in the hazards, safety precautions, and proper use of the radioactive material.
2. Understand the nature of the hazards of the material you handle. Seek advice from the RSO or other safety officer (when non-radiological hazards are also involved) whenever unsure of a situation.
3. Understand and follow the laboratory's RSP and work procedures.
4. Keep radioactive and non-radioactive work separate, and as far as possible from each other.
5. Plan work ahead to minimize time spent for handling radioactive material.
6. Ensure the radioactivity content of sources is the minimum necessary for their intended use.
7. If possible, choose a source of low radiotoxicity, and in a chemical and physical form that will minimize dispersion and the risk of contact or ingestion in case of spill or upset.
8. Properly label sources to permit identification and determination of their radiological nature.
9. Keep an up-to-date log of radioactive materials in the laboratory. The log must identify the radionuclides, their quantities, forms (solid, liquid, powder, etc.) and the date the material was brought into the laboratory.

STANDARD PRACTICES AND PROCEDURES

1. Utilize TIME, DISTANCE and SHIELDING to minimize external doses exposures to ionizing radiation.
2. Hands and shoes must be monitored for evidence of contamination every time upon leaving the area marked for radioactive work, or the laboratory (if a full laboratory is designed as area). More frequent monitoring of hands, shoes and clothing may be required while working with unsealed sources.
3. Always wash hands thoroughly with soap and water after working with radionuclides.
4. Maintain good personal hygiene, for example, keep fingernails short and clean, wear comfortable clothes to minimize perspiration, minimize work when workers have a cold and cough or sneeze, etc.
5. Wash hands and arms thoroughly before handling any object that goes to, or near the mouth, nose or eyes.
6. Solid radioactive wastes and dry materials suspected of being contaminated must be disposed of as if it was contaminated.
7. Waste disposal require manifests.
8. All receipts, transfers and disposals of radioactive material must be recorded in the logbook.
9. If an accident involving radioactive material occurs, treat serious physical injuries or chemical hazards first. With the planned activities at Laurentian University, NO short-term external radiological risk is expected to be harmful or fatal. The benefit of helping someone in need far outweighs the small radiation dose that a helping person may take.
10. Cleaning up of contaminated areas or equipment has to be checked by the RSO prior to re-use.
11. All workers must be familiar with the Building Emergency Procedures, from the University Safety policy.

USE OF FUMEHOODS

1. Consider use of additional protective measures, such as gloves or double gloves. Lab coat should be worn (they are mandatory in some departments, e.g., Chemistry & Biochemistry).
2. Use secondary containment for liquid sources (i.e., work over trays or removable plastic sheets).
3. Verify that there is adequate flow of air before starting work.
4. Keep the sash as low as possible. Equipment and movement in the hood can induce a rollover pattern, which carries fumes back towards the user.
5. When the hood is unattended, completely close the sash.
6. Keep all operations at least 20 cm from the front edge of the hood. Keep all equipment at least 30 cm from the front hood edge. In general, keep sources as far back in the hood as possible and towards the sides of the hood. Air "spillage" from the center and front of the hood is greater than the sides and back.
7. **Do not block** the baffle slots or the opening under the sill with equipment or absorbent paper. Blocked baffles or airfoils greatly decrease the hood protection factor.
8. Keep material and equipment in the hood to a minimum. If the equipment does not have legs place it on blocks (~8 cm high) to allow air flow underneath.
9. Adjust baffles so that the lower slot is wide open and the top slot is open 1 to 3 cm. For most operations, this will minimize rollover.
10. Minimize hood air flow disturbances by keeping the work space uncluttered and reducing the front opening as far as possible. Normal hand movements create eddies that may extract contaminants from the hood atmosphere to the room, keep hand and arm movements slow and deliberate.
11. Do not allow foot traffic in front of a hood that is in use. If this is not possible, place yellow tape (or similar visible tape) in front of the fume hood to remind other people to walk away from the fumehood. Eddies created by a passing person may extract air from a working hood.
12. Fumehoods should be regularly surveyed to determine radiation fields and contamination levels. Decontaminate hood surfaces, install shielding and post external radiation fields when appropriate.
13. Perform regular inspections and maintenance.
14. Have the linear face velocity of the fumehood measured at least annually for compliance with design specifications.

USE OF SEALED SOURCES

1. Store sources in shielded locations or locations remote from day-to-day occupancy. Do not store sources in the vicinity of dosimeter storage locations.
2. Be aware of external and surface dose rates. Use time-distance-shielding techniques whenever possible. Avoid touching sources directly with unprotected hands, even when handling small check sources. Use remote handling tools, such as forceps or other firm grip devices, where appropriate.
3. Whenever handling or removing a source from its container, look for abnormalities. If in doubt about the condition of a source, return it to storage and perform a self-protection test with an instrument, prior to contacting the RSO for guidance.
4. Do not leave an exposed source unattended that produces an external measurable γ radiation (above background) at 30 cm.
5. Have an appropriate radiation survey instrument immediately available when working with sources that are producing external γ or β radiation fields.
6. Handle sources in such a manner as to avoid external radiation hazards to personnel not involved with using the source. Pay attention to the hazards that could be introduced to people in adjacent areas including rooms above and below.
7. Plan work with the source ahead of time, and do practice runs of a procedure without the source, to keep exposure time as short as possible.
8. Use γ radiation shielding whenever practical when handling γ sources. Lead bricks or sheets can be used.
9. Be sure that lead bricks being used for radiation shielding are overlapped to prevent penetration of radiation at joints and that the support surface for the shielding is capable of supporting its weight.
10. Use β radiation shielding whenever practical when handling β sources. One centimeter of Plexiglas will stop all β radiation. DO NOT use lead shielding with β sources, because of the Bremsstrahlung effect (x-ray radiation) caused by high energy β emitters.
11. Verify the adequacy of the shielding by use of an appropriate radiation survey meter.
12. Ensure areas where γ radiation is used are posted with a radiation hazard warning sign.
13. If you are wearing a photobadge, place it on the area of your torso where radiation fields will be the greatest. This is normally the upper chest when handling sources in a fumehood or glove box.

USE OF UNSEALED SOURCES

1. Identify and use appropriate working methods to avoid as much as possible the generation, spread and dispersion of radioactive contamination, particularly though the formation of aerosols, gases, vapors or dusts. Allow adequate planning time for the complexity of processes and operations involved.
2. Use a fumehood or glovebox for any work with dry powder or volatile substances.
3. Protective clothing such as latex gloves, lab coats, aprons, face shields, and caps are advisable (Lab coats are mandatory in some departments, such as Chemistry & Biochemistry), depending on the level of activity, the hazard of the nuclide, and the type of work planned. Consult the RSO for advice on necessary protection. Contamination prevention is far less costly than decontamination
4. Do not work with radioactive materials if you have open cuts or abrasions.
5. Do not handle radioactive materials with unprotected hands. Wear gloves to prevent hand contamination. As a rule, use double gloves with the inner glove taped to the lab coat sleeve when performing complex operations with liquids or powders where the potential for hand contamination is high.
6. Remove, if possible, jewelry, and any sharp objects that might penetrate a glove when it is put on or used in the manipulation of radioactive material. Limit or avoid the use of pointed tools, wire or containers, glassware or other equipment with sharp edges, or long nails, which could puncture gloves and the skin.
7. Change contaminated outer gloves frequently. Outer gloves should be removed and discarded into a waste container inside the fumehood or over the working bench's working surface. Be careful not to touch the inside glove or unprotected skin when removing gloves.
8. Monitor hands, clothing and work areas for contamination after each procedure. Wash hands immediately following work completion. Do not needlessly contaminate objects such as switches, door knobs and other surfaces by handling them with potentially contaminated
9. ~~hands~~ pipette by mouth.
10. Carry out operations with the potential for generation airborne aerosols in a fumehood. This would include the use of blenders, opening recently centrifuged test tubes, the use of ultrasonic devices, heating, or other similar procedures.
11. Cover working surfaces on workbenches and floor surfaces outside of fumehoods where sources are handled with a non-porous disposable material (e.g., plastic sheet). This is to facilitate decontamination should the surface become contaminated.
12. Use a secondary container when handling or storing radioactive liquids. Containment should have sufficient volume to contain minor or major spills. If liquids are being handled, a disposable absorbent material can be placed over the containment surface to soak up any minor spills. Change absorbent material and damp wipe areas frequently to prevent accumulation of contamination.
13. Place handling tools and equipment used with unsealed sources in non-porous trays lined with disposable material. Change lining frequently. Do not place pipettes, stirring rods and similar equipment used with radioactive materials directly on a bench or table.
14. Be aware of dose rates from radioactive samples and other sources handled. Use good time, distance and shielding practices to control external exposures.

15. Use shielding whenever possible and if appropriate. Pipette from shielded containers, put containers behind or into shields when not actually in use.
16. Transport sources in adequately shielded containers.
17. Transport radioactive materials in the liquid, gaseous or other dispersible in packages consisting of an inner and outer container. The outer container should be sufficiently durable to prevent accidental release of the material in case of an upset. For liquids, the outer container should be capable of containing all of the liquid should leakage from the inner container occur. Absorbent material capable of absorbing all of the liquid should be used.
18. Visually inspect source containers for damage or leakage before using them.
19. Label all containers of radioactive material. This includes waste containers, vials, test tubes, flasks, beakers, etc., in addition to the primary and diluted source solutions.
20. Collect all waste in properly labeled cans.
21. Do not eat, drink, or apply cosmetics in any area where radioactive material is stored or in use. Do not store food or drink with radioactive material.
22. Be aware of the chemical properties of the radionuclides you are working with to avoid uncontrolled releases of activity. Tritium, radioiodines, polonium, ruthenium, plutonium and many others form chemically mobile (i.e., volatile or fine particles) compounds. Others such as ^{226}Ra give rise to volatile daughter products.
23. Monitor equipment, material, samples and supplies before removing from laboratory. Record removal or addition of radioactive substances in the Laboratory log book.

STORAGE OF RADIOACTIVE MATERIALS

1. When not in use, place radioactive materials in a dedicated storage area. It is advisable to lock sources.
 2. Do not handle radioactive materials as open sources in storage areas.
 3. Make sure the storage area is adequately shielded so that the external dose rate outside the area not significantly above the laboratory background.
 4. Post the storage area with a hazard warning sign that has the radiation trefoil symbol and the words "RADIATION-DANGER-RAYONNEMENT".
 5. Clearly label all stored materials as radioactive.
 6. A qualified person must be responsible for the storage area.
 7. Only authorized or qualified personnel should move sources into and out of the storage area.
 8. Inspect and survey the storage area regularly from possible contamination.
 9. Place β emitters in containers with appropriate β shielding material (e.g., aluminum or glass). Considerable Bremsstrahlung radiation may arise from high intensity sources stored near lead shields.
 10. Store sources with a potential for releasing radioactive gas or vapors in a ventilated storage area.
 11. Place bottles containing radioactive liquids in a secondary container or tray sufficiently large to hold the entire contents, in case of leakage or breakage. It should be borne in mind that that all glass containers can fail without apparent cause, and plastic containers have a limited shelf life because of radiation effects.
 12. Use storage containers that are easy to open.
 13. Keep records of all stored radioactive material. Records should give clear information on the type and quantity of the material, the date when the source was entered to the record, and the user of the material.
 14. Check the inventories periodically.
-

APPENDIX H:

PROCEDURES IN CASE OF UPSET, EMERGENCY OR OTHER NON-ROUTINE EVENTS.

Note: these are recommended actions with respect to reacting to emergency situations while working with radioisotopes. The intent of this section is to minimize the spread of contamination and/or radiological risk in case of an upset. Appropriate reaction to a greater danger (e.g., fire) should supersede these measures, if, to the judgement of the person(s) or co-workers, the other risk outweighs the radiological risk.

GENERAL PRINCIPLES:

1. Do not work with or handle radioactive materials alone. There should always be someone in close proximity (within the sound of your voice) to help in case of incident or upset.
2. Be familiar with local building emergency procedures.
3. Contact the RSO and the Laboratory Supervisor for assistance in case of incident or upset that could lead to an increase in dose, or that could lead to contamination outside the containment area.
4. At least one tap should have a hands-free operation to minimize the risk of contamination.
5. Clear the area where the contamination occurred. Persons not involved in the incident should leave the area immediately unless help is necessary. Limit the movement of all personnel who may be contaminated until they are monitored.
6. Take immediate steps to confine contamination. If possible, cover the contamination with absorbent material to prevent the spread of contamination. If the contamination occurs in the laboratory work area, leave the fumehood sash open to ventilate the area.
7. Close off and secure the contaminated area to prevent entry. Post warning signs.
8. Notify the RSO and the Laboratory Supervisor or designate as soon as possible, because if the event leads to a significant radiation exposure or contamination, it must be reported by the University to the Ministry of Labor, or to the CNSC, or to both.
9. The trained workers or Laboratory Supervisor should initiate clean-up as soon as reasonably possible.
10. Obtain assistance from the RSO to check for loose contamination after clean-up.

SPECIFIC EVENTS OR UPSETS:

If you discover a fire:

1. Pull the nearest fire alarm switch, or ask someone to do so.
2. Phone Security (9-911) to report the location of the fire, or ask someone to do so.
3. If practical or safe, and if the fire is small, use the fire extinguisher to fight the fire. Never let a fire get between you and a safe exit.
4. If practical, secure the workplace to minimize the spread of contamination.
5. If the fire is too large to be controlled, or if your safety or the safety of other people is at risk, all should leave the laboratory and close the door.
6. If the fire is in the fumehood, if practical, close fumehood sash as well.
7. Inform the RSO immediately or ask someone else to do so.
8. Meet with Security or the firefighting personnel to inform them of the situation with respect to radiological hazard.

Other fire alarm

1. If practical, secure the workplace to minimize the spread of contamination.
2. Leave the laboratory and close the door.
3. If necessary, or if the fire could spread towards the laboratory, meet with Security or the firefighting personnel to inform them of the situation with radiological hazard.

Minor spills in a fumehood or a countertop

1. Clean up the spill immediately using damp towels.
2. Dispose of the towels in an appropriate radioactive waste container.
3. Perform a self-protection test with a radiation survey instrument to determine if you are contaminated.
4. Request the RSO assistance to survey the spilled area.
5. The RSO may institute a more thorough decontamination if required.
6. Depending on the nature and quantity of the radioisotope in the spill, it may be wise to seal the garbage container and dispose of it immediately.
7. Update the laboratory logbook inventory to account for the spilled material

Major spills in the laboratory

1. Clean up the spill immediately using damp towels, or use towels to minimize the spread of contamination and the potential for the radioactive material to get to the floor drain.
2. Use disposable material (towels, tape, plastic, etc.) to delineate the approximate contaminated area. This minimizes the risk of personnel inadvertently walking or spreading
3. ~~Contain the area~~ immediately and close the laboratory door.

4. Ask someone to call the RSO immediately for assistance, or do so yourself if practical or if there is no risk of spreading contamination.
5. Wait there until assistance is available to minimize the spreading of contamination.
6. With appropriate assistance, monitor hands, feet, potentially exposed skin and apparel (i.e., lab coat, etc.). If applicable, remove contaminated apparel and go to the nearest shower to wash. Ask for assistance to bring clean clothes.
7. With the help of the RSO, notify Security or other health and safety representative to report and assess the situation.
8. Nobody shall enter the laboratory, except for workers who may be allowed in temporarily to take personal effects, under the supervision of the RSO or the laboratory supervisor. The workers must leave immediately afterwards.
9. Laboratory re-entry for work must be approved by the RSO.
10. Dispose of the contaminated material appropriately.
11. Update the laboratory logbook inventory to account for the spilled material.

Ventilation or power failure

1. Any work involving volatile radioisotopes, the potential for volatilization, or the potential to produce airborne radioisotope should be stopped.
2. Close all fumehood sashes immediately, and secure the workplace to minimize the potential to produce a spill or airborne contamination.
3. Turn off the electrical power to hot plates, stirrers, heating mantles, etc., in the fumehoods and workplace.
4. Vacate the laboratory immediately, and close the laboratory door.
5. If the event is just a ventilation failure, notify the Laboratory Supervisor or the RSO of the event.
6. Consult with the Laboratory supervisor or the RSO if the conduct of operations should continue.
7. If the laboratory was vacated, assess the safety of the workplace prior to starting work. If in doubt, consult with the Laboratory supervisor or the RSO.

APPENDIX I:

SELF-VERIFICATION MEASUREMENTS (SVMs)

Purpose

To test the potential for contamination release in frequently used or traveled areas of a laboratory or a workplace.

General Procedures for SVMs

The laboratory or workplace must be clearly delineated (see Figure I-1), along with designated areas for daily SVM and weekly SVM. A meter equipped with a thin window detector (Frisker or pancake-type), with a valid calibration sticker, should be used.

Daily Work Area Contamination SVMs

These tests are to be performed daily whenever unsealed sources of radioactivity are handled in a licensed laboratory, to confirm that the potential for contamination remains very low. Daily SVMs should be performed at least as frequently as the work with radioisotope.

Procedure:

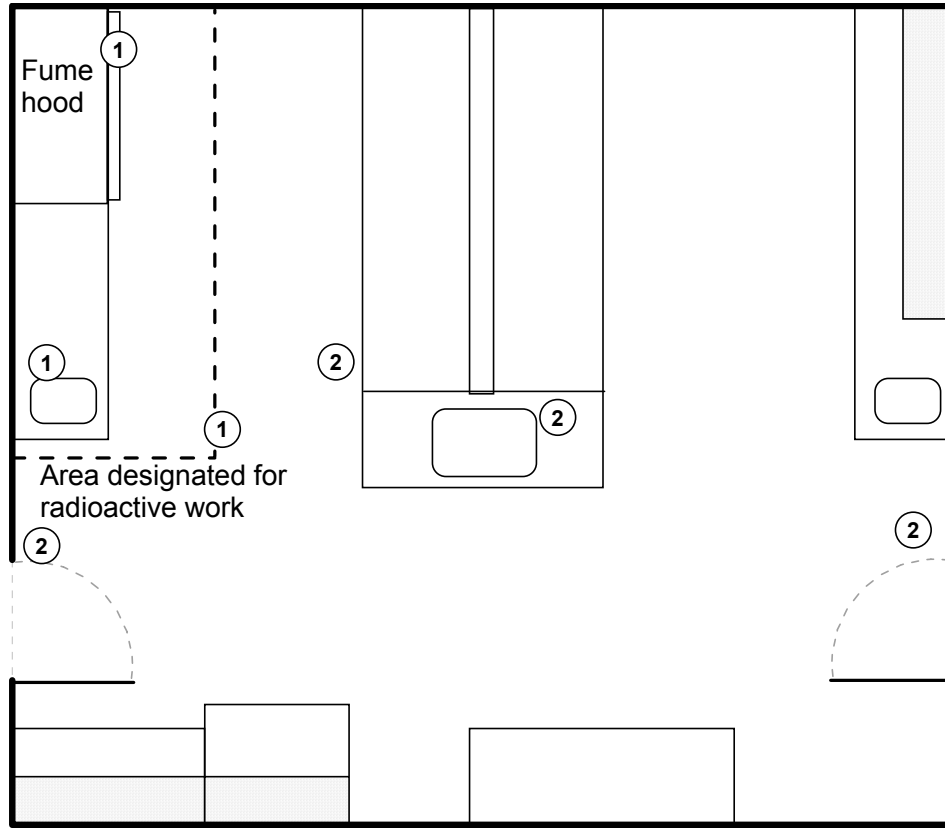
- In handling locations: wearing rubber gloves, swipe an area of approximately 100 cm² on the ledge of the fumehood or work area.
- Count the swipe using a ratemeter.
- Ensure that the gross counts on the swipe are less than 100 cpm (including background).
- If higher than this value, contact the laboratory supervisor.

Weekly Laboratory Surfaces SVMs

These tests are to be performed weekly whenever unsealed sources of radioactivity were handled in the laboratory. The tests should be done when a source has been handled, or when a source is not in storage. The weekly SVM is an additional test to confirm that contamination is not unknowingly being spread outside the work area, and outside the laboratory.

Procedure for Handling Locations and Traffic Areas:

- Refer to daily SVM for handling locations.
- Traffic areas: wearing rubber gloves, swipe an area of approximately 100 cm² at any location outside the fumehood where the sources could have been handled, and at other locations where contamination may have spread. These include, but not necessarily limited to taps, light switches, just outside the designated area, telephone headset, etc.
- Count the swipe using a ratemeter.
- Ensure that the gross counts on the swipe are less than 100 cpm (including background).
- If higher than this value, contact the laboratory supervisor.



Example of typical laboratory with locations designated for SVM. 1. Daily SVM; 2. Weekly SVM.

APPENDIX J

EXAMPLE OF RADIOISOTOPE LOG SHEET

Laboratory: _____
 Isotope and quantity: _____
 Source/Lot No: _____
 Reference date: _____
 Location of source: _____
 Log book: _____

Use #	Date used	
	User	
	Amount taken (units)	
	Intended use	
	Waste Management	<input type="checkbox"/> Store/decay <input type="checkbox"/> Municipal disposal <input type="checkbox"/> Drain disposal <input type="checkbox"/> Other (specify)
	(date)	
	Contamination check	(person's initials, attach documents) _____
<input type="checkbox"/> Source (after use) <input type="checkbox"/> Daily <input type="checkbox"/> Weekly/end <input type="checkbox"/> waste container		
Use #	Date used	
	User	
	Amount taken (units)	
	Intended use	
	Waste Management	<input type="checkbox"/> Store/decay <input type="checkbox"/> Municipal disposal <input type="checkbox"/> Drain disposal <input type="checkbox"/> Other (specify)
	(date)	
	Contamination check	(person's initials, attach documents) _____

	__ Source (after use)	__ Daily	__ Weekly/end	__ waste container
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APPENDIX K
RADIATION WARNING SIGNS



APPENDIX L

CHECKLIST FOR ROUTINE INSPECTIONS

- _____ Radiation Warning sign is posted;
- _____ Radioisotope is listed on Warning sign;
- _____ List of authorized users is up-to-date;
- _____ List of authorized users is posted;
- _____ Appropriate sign (INFO 0728) with contact person and phone number is visible;
- _____ Copy of current license is visible or easily available on location;
- _____ Location of log book is known to everyone in the lab;
- _____ Log book is complete and up-to-date;
- _____ The radioactive sources are readily found;
- _____ The information in the log book must be easy to read and cross-referenced against the sources;
- _____ Contamination checks are readily available and are referenced in the log book;
- _____ NO food items in the lab at ALL TIMES. This includes (but not limited to) the following:
 - Food bags, lunch pails, etc., (full or empty) on location;
 - Food wastes (or evidence thereof) in garbage containers;
 - Drinks or empty drink containers (cups, pop, coffee, etc.).

Distribution list:

CNSC

N. Ringuette

Laurentian university

J. Benoît Health and Safety Manager

B. Rayakovich Head, Human Resources

R. Haq Dean, Faculty of Science and Engineering

D. Hallman Associate RSO (Laurentian Campus)

Z.Z. Wang Associate RSO (Elliot Lake Research Field Station)

G. Morgan Manager (Elliot Lake Research Field Station)

R. Coutu Purchasing and Insurance Services

S. Chrétien-Makela

R. Bertoli Physical Plant

Users and Departmental Technologists (this list can change)

E. Gauthier

R. Michel

G. Ferroni/G. Leduc

G. Clark

A. Omri

A. Kumar

C. Bloome

G. Cowper-Benoît

EMERGENCY NUMBERS (Laurentian University Campus):

SECURITY

Ext. 6562
9-673-2661 (after hours and on weekends)

FIRE

9-911

RSO

Ext. 2400 (Dr. F. Caron, Chemistry & Biochemistry Department, office F-526)

Ext. 2231 (Dr. D. Hallman, Department of Physics and Astrophysics, office F-513)
(associate RSO)

705-461-8375 (Dr. Z.Z. Wang, Elliot Lake Research Field Station. Associate RSO).