The Radiation Safety Manual, Policies and Procedures

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I. THE RADIATION SAFETY PROGRAM AT SFU

The use of radiological materials (radioactive materials and/or equipment generating ionizing radiation) is regulated in Canada by the Canadian Nuclear Safety Commission (CNSC), and provincially by WorkSafeBC. The CNSC issues a consolidated radioisotope license for Simon Fraser University. The license specifies conditions of usage of the prescribed substances. Compliance with the license conditions and SFU policies and procedures is monitored by Radiation Safety staff through internal compliance inspections. The Compliance Division of the CNSC and WorkSafeBC inspectors are responsible to ascertain that the requirements of the Nuclear Safety Control Act and CNSC regulations are being fulfilled; they inspect the institution at regular intervals to verify that the University community is in compliance with those regulations and with the radioisotope license conditions (See Appendix V for Inspection forms).

SFU's Radiation Safety Program is an integral component of Environmental Health & Safety. The structure of the Radiation Safety Program at SFU is described by policy R20.04, Radiological Safety, available on the web at:
http://www.sfu.ca/policies/gazette/research/r20-04.html

It is a condition of this policy that all activities involving radiological materials at SFU:

- Be justified that no activity using radioactive materials be undertaken unless it can be demonstrated that it will produce a positive net benefit.
- Keep exposures to ionizing radiation As Low As Reasonably Achievable, the ALARA principle.

A. The University Radiation Safety Committee (URSC)

The SFU University Radiation Safety Committee (URSC) provides internal auditing of the Radiation Safety program. For a list of current committee members, see http://www.sfu.ca/srs/ehs/research-safety/rso/ursc/committee-members.html It is the responsibility of the URSC to:

- ensure the development, implementation and compliance with policies, regulations and procedures for ordering, safe use, handling, monitoring, storage and disposal of radiological materials which fall under the legislative control of the CNSC and of the use of equipment that emits ionizing radiation regardless of the source of authorization at the University;
- review, at least annually, the entire Radiation Safety Program to determine if all activities meet the conditions of the license and the CNSC Regulations;
- receive reports from the Director of Research and Laboratory Safety and recommend remedial action to correct any deficiencies;
- review the annual report prepared by Program Manager, Ionizing Radiation Safety and once approved, forward a copy of this report to the CNSC and the Vice-President, Research;
- review actions taken by Program Manager, Ionizing Radiation Safety for non-compliance with CNSC and other rules and regulations (see Section II Measures to Promote the Safe Use of Radiological Materials);
- in general, act as the internal auditor of the functioning of the Radiation Safety Program at Simon Fraser University;
• recommend changes to this policy to the Vice President, Research, who has the authority to approve such changes.

B. The Radiation Safety Program

The Radiation Safety Program is one of several research safety programs reporting to the Director, Research and Laboratory Safety. The Program Manager for Ionizing Radiation functions as the Radiation Safety Officer. The following activities are essential activities of the Radiation Safety Program:

• plan, develop and manage a radiation safety strategy to promote compliance with the regulations of the CNSC, other federal and provincial bodies, and conditions of the University radioisotope license;

• develop, recommend and implement policies and procedures for the safe use of Radiological Materials in accordance with the current CNSC guidelines and those of other pertinent regulatory agencies;

• advise the Vice-President, Research and the Chief Safety Officer on matters related to radiological hazards and radiological safety, including the resources necessary to set up and maintain an adequate Radiation Safety Program in conjunction with ALARA principles;

• advise the University Radiation Safety Committee (URSC) on matters regarding radiological safety;

• be available for consultation on problems dealing with radiological materials and radiation hazards;

• prepare, update and arrange for the distribution of the "SFU RADIATION SAFETY MANUAL," containing all information pertinent to the use of radiological materials at Simon Fraser University;

• receive applications for and give detailed review to all proposed uses of radioactive chemicals and equipment which the University has been licensed by the CNSC to acquire and use;

• designate local conditions for radiation protection for each application; these shall be consistent with the conditions of the consolidated license and the requirements of the regulations, policies and procedures for radiation safety at Simon Fraser University and with ALARA principles;

• issue permits approved by the Radiation Safety Officer and the Director, Research and Laboratory Safety for proposed uses and users within the University subject to compliance with the conditions specified above;

• develop and maintain a certification training program to ensure that all individuals who may be required to work with radioactive materials are properly instructed;

• develop, deliver and maintain training and information programs to ensure that all employees who may be required to work in the vicinity of radiological material are properly instructed;

• designate any individual to be considered as an Nuclear Energy Worker (NEW) under the CNSC Regulations;

• maintain written records of all meetings, action, incidents or unusual occurrences and recommendations, as well as decisions, and forward a copy of these records to the CNSC;
• approve designs of new laboratories and the decommissioning of existing laboratories in accordance with CNSC regulations;
• ensure by regular inspections that proper procedures are in place to control the purchases, storage, use, disposal and transport of Radiological materials;
• ensure that records associated with use of Radiological materials are properly maintained;
• investigate reports of user infractions of policies, procedures and guidelines and initiate corrective and/or disciplinary action;
• maintain a program of leak-testing of sealed sources on campus;
• maintain a program of personal-exposure monitoring;
• develop and coordinate emergency response for incidents involving radiological materials; supervise decontamination operations where required;
• prepare the Radiation Safety Annual Compliance Report according to CNSC guidelines for such document;
• prepare when requested by the CNSC the renewal application for the University radioisotope license;
• audit the University Radiation Safety Program to identify deficiencies and initiate steps to address outstanding issues;
• enact the Enforcement Policy to ensure that compliance is maintained
• conduct investigation of all incidents involving radiological materials and recommend actions to prevent reoccurrence;

C. The Permit Holder

The permit holder is an employee of the University, typically a faculty member, who has training and experience acceptable to Radiation Safety staff, in the safe handling of radioactive materials and devices. The permit holder is responsible to:

• initiate a review and seek prior approval from Radiation Safety staff for any research and/or teaching program using radiological materials;
• ensure that safe laboratory practices are followed in compliance with the University’s radiation protection standards and the safe laboratory practices stated in the current revision of the CNSC "Laboratory Rules Poster."
• ensure that operations involving radiological materials are performed only in locations authorized in the permit;
• ensure that only individuals authorized on the permit perform operations with radiological materials;
• ensure that all users have received adequate radiation protection training or experience and have been informed of the risks of exposure to ionizing radiation. Permit holders are responsible for providing specific training in radioisotope handling that is necessary for the safe use of radioisotopes in their laboratories;
• designate specific work and storage areas for radiological materials and ensure that these areas are clean, properly labeled and have adequate ventilation and shielding;
• post warning signs and labels as required by the CNSC and University regulations
and policies;
- ensure that personnel wear appropriate radiation badges or pocket dosimeters when and if required;
- maintain an inventory of radiological materials used in his or her project(s), and ensure that the activity in hand does not exceed the limits authorized in the permit;
- maintain records of the disposal of radiological materials;
- allow only authorized persons to enter rooms that are specified as restricted areas for reasons of radiation protection;
- establish a laboratory procedure to ensure, at the end of the laboratory work day, that:
  - survey-meter measurements and/or wipe tests have established that external radiation and contamination levels are within permissible limits;
  - radiation sources are properly labeled and stored;
  - experiments that will be in progress after normal working hours will be either properly attended or secured;
  - each laboratory is secured against unauthorized access;
- ensure that weekly contamination swipe tests are performed and the results recorded;
- report promptly to Radiation Safety staff all incidents involving release, loss or theft of Radiological materials;
- ensure compliance with all relevant standards including CNSC guidelines and Simon Fraser University Radiological Safety policies and procedures;
- develop, in cooperation with Radiation Safety staff, appropriate emergency and decontamination procedures for his/her area of work;
- ensure that all operations comply with the conditions of the permit.

D. The Authorized User

Radioisotope users must be authorized by Radiation Safety staff to handle radiological materials and their name must appear on the permit of the permit holder for whom they wish to work. Authorized users are required to:
- have a working familiarity with SFU Radiological Safety policy and procedures;
- follow specified work procedures;
- use appropriate protective equipment;
- report promptly to the Permit Holder and to Radiation Safety staff any incidents, loss, theft or accidents involving the use of materials;
- bring to the attention of the permit holder any defect in the operation of which they are aware.
II. MEASURES TO PROMOTE THE SAFE USE OF RADIOLOGICAL MATERIALS

The failure of an individual to conform to the conditions of the radioisotope license issued to the University by the CNSC may result in severe consequences for the University as a whole. These consequences may include a threat to the safety of the campus or surrounding community and environment, the loss of the license and immediate cessation of all research involving radioactive materials by all users, and substantial monetary fines. As a result, the University Radiation Safety Committee has established a policy to ensure that the license conditions will be met.

A. Principles:

- Undue risk to the workers, the environment and/or to public safety will be met with prompt corrective action.
- CNSC rules, even though they may appear on occasion to be troublesome, are designed to ensure public safety. If there are special cases for which they do not make operational sense, the Program Manager, Ionizing Radiation Safety will request a suitable amendment or exemption to the Simon Fraser University radioisotope license.
- The permit holder is responsible to provide a safe environment for those working under his/her permit and to ensure that work is conducted according to regulations.
- The Program Manager, Ionizing Radiation Safety has the authority and the responsibility to initiate corrective and or punitive actions when and where warranted.
- Violations of the terms of this policy may result in disciplinary action.

B. Procedures:

- If a danger to public safety is observed then, apart from any other action, the dangerous situation will be rectified promptly and those responsible for creating the situation will have their permission to work with and/or use Radiological materials immediately suspended.
- For record keeping deficiencies, coffee cup/food offences, other similar unsafe practices and violations of permit conditions:
  1st offence: written warning to the permit holder and the offender, with a record of the warning on file; cups and food will be confiscated if not removed promptly after the warning.
  2nd offence: (includes items of noncompliance found during a re-inspection) written notice to the permit holder and the offender stating that any further infraction will result in suspension of the permit; immediate confiscation of cups and food.
  3rd offence: suspension of the permit with notification to the Department Chair and to the University Radiation Safety Committee (URSC). Work under this permit will be allowed to resume once the permit holder has provided a written review of utilization of Radiological materials under the permit in the past 6
months and a satisfactory plan for compliance for the future. The offending individual will be removed from the list of authorized users and can only obtain reinstatement by attending the Radioisotope Safety Course to the satisfaction of Radiation Safety staff.

Offences over a year old will not be counted, and offences of distinctly different natures will be counted separately.

- If, after reinstatement under item 2, there are further infractions, the individual will be removed from the list of authorized users and the permit suspended; the permit holder may appeal to the URSC for restoration of the permit and reinstatement of the offender. The committee may recommend:
  - cancellation of the permit until the permit holder satisfies conditions deemed appropriate by the URSC,
  - no reinstatement of the offending individual,
  - further attendance at a Radioisotope Safety Course,
  - work permitted under continuous visual supervision,
  - other restrictions or actions deemed appropriate.

- If, in the opinion of Radiation Safety staff, there is a major violation of the terms of this policy, an allegation of misconduct may be filed against the individual responsible. Examples of major violations include, but are not limited to, unauthorized, mischievous or malicious uses (or unauthorized, mischievous, malicious interference with approved uses) of radiological materials and intentional disregard of any of the regulations governing the safe handling of radiological materials. If this occurs in a research setting, an allegation of misconduct in research may be filed under Simon Fraser University Policy R60.01. If this occurs in a non-research setting, an allegation of misconduct may be filed under the terms of the policy or collective agreement relevant to that setting and to the employee or student group to which the alleged offender belongs. If there is no appropriate policy or collective agreement for consideration of the allegation, it may be filed with the Vice President, Research and considered according to the procedures contained in Simon Fraser University Policy R60.01, which can be viewed at: http://www.sfu.ca/policies/gazette/research/r60-01.html

C. Appeals

Decisions of Radiation Safety staff may be appealed to the URSC whose decisions are final. Appeals of other decisions, made under the provisions of item 4 above, may be made through the appeal or grievance mechanism contained in the policies applied therein.
III. TRAINING REQUIREMENTS

Versions of Radioisotope Safety training are offered to the following campus groups:

- Research personnel
- Campus Trades personnel
- Campus Safety and Security personnel
- Science Stores personnel
- Janitorial personnel

The URSC has made it a requirement that all new prospective users or new internal permit applicants, regardless of previous training, must complete Radioisotope Safety Training at SFU. Since the training is usually offered on a semester basis, new users may begin radioisotope work prior to taking Radioisotope Safety Training under the following conditions:

- if they have previous experience and training in the use of radioisotopes, but are new to SFU, they may begin radioactive work once they are authorized by the RSO, provided that they meet with the Radiation Safety Technician for immediate training in SFU procedures for ordering and handling of isotopes.
- if they are new radioisotope users, they may begin work once they are authorized by the RSO, provided that they meet with the Radiation Safety Technician for immediate training in SFU procedures for ordering and handling of isotopes and undertake all radioactive work under the direct line-of-sight supervision of a trained and authorized radioisotope user.

In either of these above cases, should these users not complete the next available Radioisotope Safety Training Course, their radioactive work privileges will be suspended and in the case of permit holders, their permits will be revoked until such time as they complete the required training.

For research personnel:

to view current training schedule, see [https://www.sfu.ca/srs/ehs/research-safety/rso/rso-training.html](https://www.sfu.ca/srs/ehs/research-safety/rso/rso-training.html)

For the remaining training groups special training dates are arranged when required.
IV. AUTHORIZATION TO USE RADIOACTIVE MATERIALS

A. The Radioisotope Permit

Prior to undertaking radioactive work, a researcher must submit an application for an internal permit to Radiation Safety staff outlining the research project, the isotope(s), and expected quantities to be used. Applications for a radioisotope permit are available in Appendix II (see Permit Application form). Once issued, a copy of the permit is to be posted on the outside of the door of each authorized room.

B. Amendments of Permits

Permit holders are responsible for notifying the Program Manager, Ionizing Radiation Safety of any changes in authorized personnel, rooms, isotopes in use, or projects. Notification can be made via email.

C. Renewal of Permits

- Permits expire on the date specified on the existing permit.
- Preceding the expiration date there will be a period of conditional approval. This period is indicated on the permit.
- At least a month before the start of the conditional approval period the Program Manager, Ionizing Radiation Safety will contact the permit holder to determine whether renewal is required and if any amendments are necessary.
- If no requests for renewal have been received by the Program Manager, Ionizing Radiation Safety at the start of the conditional approval period the permit will have expired at that date, otherwise the permit will be extended to the expiry date.
- A current inventory of radioactive materials in stock has to be verified and provided on an annual basis.

D. Teaching Permits

The teaching of laboratory courses in which radioisotopes are handled requires that the person in charge of the course obtains a temporary permit from the Program Manager, Ionizing Radiation Safety. This authorization will be granted at the beginning of each term once the following information is received:

- instructor name,
- class list,
- outline of experiment(s) involving radioactive materials.

The temporary permit will be issued by Radiation Safety staff if the experiment(s) are approved. One of the conditions of the permit is that a safety presentation be given to the
students at the beginning of the term by Radiation Safety staff or an approved individual (usually the course instructor).

E. Internal Radioisotope Permit

The following shows a sample internal radioisotope permit

SIMON FRASER UNIVERSITY
INTERNAL RADIOISOTOPE PERMIT

Permit No: 06110
Date of Issue: 1 May 2017
Review Period: January 2019
Expiry Date: 30 April 2019

1. Name, address and telephone number(s) of Permit Holder:

Name
Telephone: 778-782-3506
Department
email:
Simon Fraser University
Burnaby, B.C.
V5A 1S6

Contact Person:

2. Name(s) of persons, other than Permit Holder approved for work with Radioisotopes

3. Approved Isotopes:

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Possession Limit</th>
<th>Handling Limit</th>
<th>Handling Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fume Hood</td>
<td>Open Bench</td>
<td></td>
</tr>
<tr>
<td>P-32</td>
<td>370 MBq</td>
<td>370 MBq</td>
<td>37 MBq</td>
</tr>
</tbody>
</table>

4. Locations approved for the use of Radioisotopes:

Basic: SSB 6134, SSB 6136, SSB 6152, SSB 6154, SSB 7167, SSB 7135, SSB 6130
Intermediate: SSC-B7249, SSB 7139, SSB 6160

5. Approved usage:

For studies of radiation effects on biological systems and thermo luminescence and optical dating research.

6. Method of Isotope Disposal:

Solid and liquid waste to be returned to Room SSC-B7249.

continued...
7. Other Conditions of Approval:

a) All sources shall be marked with a radiation warning symbol in accordance with the Nuclear Safety and Control Act.

b) Only the persons mentioned under Sections 1 and 2 will be allowed to handle the radioisotopes listed above without direct supervision. Those persons shall receive instruction in the safe handling and storage of radioisotopes and be made aware of the potential hazards of such use.

c) User wipe tests and area monitoring must be done at minimum on a weekly basis after handling open radioactive sources and a record kept of the results.

d) All sources shall be accounted for and an up-to-date inventory is to be kept.

e) A waste stream analysis and record must be made of all waste generated and its location.

f) No radioactive materials may be used in experiments involving human subjects.

g) An inventory of radioisotopes and a review of permit conditions must be submitted annually to the Program Manager, Ionizing Radiation Safety upon request.

h) The monitor shall be used with the audio signal on while handling P-32.

i) This permit expires on 31 January 2019, unless a request for renewal has been received by the RSO by that date. Upon receipt of this request for renewal before the aforementioned date, this permit will be extended to 30 April 2019.

The use of the above-mentioned material(s) is authorized by the SFU Radiation Safety Committee subject to the conditions of approval stated herein and otherwise subject to the provisions of the SFU Radiation Safety Manual.

Radiation Safety Officer

Date

Director, Research and Laboratory Safety

Date
V. ACQUIRING RADIOACTIVE MATERIAL

A. Procedure For Ordering

- All purchases of items or apparatus containing radioactive sources must be approved by the Program Manager, Ionizing Radiation Safety or the Radiation Safety Technician (RST). An order system is available online through Science Stores. Radioactive items need to be checked off on the order requisition for approval.
- The requisitioner must be an approved user.
- The quantity of material ordered must be such as not to exceed the possession limit indicated in his or her internal permit.
- Although purchase requisitions are screened by Science Stores and/or by the Purchasing Department, it is the responsibility of the person placing the order to ensure approval has been granted.
- As a result of the Nuclear Non-Proliferation Treaty, some radionuclides are safeguarded and cannot be imported into Canada without a permit. See Table V.1 Items Requiring an Import Permit for a list of items requiring an import permit. Contact Radiation Safety staff well in advance of your study if you wish to import any of the listed items.

<table>
<thead>
<tr>
<th>Deuterium</th>
<th>Uranium</th>
<th>Mendelevium 258</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plutonium</td>
<td>Actinium 225, 227</td>
<td>Neptunium 235</td>
</tr>
<tr>
<td>Thorium (&gt; 0.05% by weight)</td>
<td>Californium 248, 250, 252, 253, 255</td>
<td>Polonium 208, 209, 210</td>
</tr>
<tr>
<td>Tritium*</td>
<td>Fermium 257</td>
<td>Radium 223</td>
</tr>
<tr>
<td>Some sources of Neptunium 237*</td>
<td>Gadolinium 148</td>
<td>Some sources of Americium 241, 243*</td>
</tr>
<tr>
<td>Some sources of Radium 226*</td>
<td>A neutron generator</td>
<td></td>
</tr>
</tbody>
</table>

*Consult Radiation Safety Officer for detailed information

B. Transfers of Radioactive Materials

Transfers of radioactive materials to or from another laboratory at SFU or at another institution, or to an individual off-campus must be approved by the Program Manager, Ionizing Radiation Safety. Incoming transfers must have an inventory sheet issued by the RST and must be included in lab inventories.
VI. THE RADIATION AREA

A. Laboratory Design

Radioisotopes are to be used only in those laboratories which conform to the specifications of the Canadian Nuclear Safety Commission and Guidance Document GD-52, “Design Guide for Nuclear Substance Laboratories and Nuclear Medicine Rooms.”

- the radiation handling area should be located to minimize movement of radioactive materials
- the laboratory should be at negative pressure relative to other areas
- a fume hood is mandatory if radioactive aerosols or gases are to be used,
- fume hoods should not be located near the entrance to the laboratory.
- all surfaces and furniture shall be finished with smooth, impervious, washable, and chemical resistant finish
- at least one chair or stool must be covered with a vinyl or plastic sheet.
- radioisotope laboratories must have sufficient floor and countertop space to allow persons to work safely; three square meters (30 square feet) of free floor area per person should be provided.
- no food or beverage preparation, consumption or storage in the lab.
- no desks or study facilities in radioactive handling areas.
- provision should be made for emergency lighting in the lab.

Table VI-1. Exemption Quantities for commonly used radioisotopes

<table>
<thead>
<tr>
<th>ISOTOPE</th>
<th>Exemption Quantity (EQ)/MBq</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-32</td>
<td>0.01</td>
</tr>
<tr>
<td>C- 14</td>
<td>10</td>
</tr>
<tr>
<td>H- 3</td>
<td>1000</td>
</tr>
<tr>
<td>P-33</td>
<td>100</td>
</tr>
<tr>
<td>I-125</td>
<td>1</td>
</tr>
<tr>
<td>S-35</td>
<td>100</td>
</tr>
</tbody>
</table>
B. Bench Preparation and Location

- the radiation bench should be located to minimize movement of radioactive materials,
- the radiation bench area must be clearly delineated with radiation warning tape,
- bench cover should be used with the absorbent surface facing up,
- where large volumes of liquids are handled the work should be done in diaper-lined trays such that if a spill does occur all the liquid is contained.

C. Laboratory Classification

A laboratory is not deemed radioactive unless there is more than 1 Exemption Quantity (EQ) in use. Table VI-I lists the EQ value for some commonly used radioisotopes.

The CNSC has four categories of radioactive laboratories: Basic, Intermediate, High Level, and Special Purpose. The laboratory classification is determined by the radionuclide in use and the potential exposure. Potential exposure is characterized by the Annual Limit of Intake (ALI), which is the amount of isotope which if ingested or inhaled would result in a yearly committed effective dose of 20 mSv. The laboratory classification is determined by the number of ALIs used at one time in the laboratory (See Table VI-2 below for the ALIs and associated laboratory classifications).

Note that laboratories in which sealed radioactive sources are used and storage areas are not classified, although they still require an internal SFU radioisotope permit if the activity of sources exceed the exemption quantities. Shielding shall be provided to ensure that workers are not exposed to radiation levels in excess of 25 µSv hr⁻¹ (2.5 mRem hr⁻¹); in most cases, workers should be shielded such that fields do not exceed 2.5 µSv hr⁻¹ (0.25 mRem hr⁻¹).

<table>
<thead>
<tr>
<th>Laboratory Designation</th>
<th>Maximum ALI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Intermediate</td>
<td>&lt;50</td>
</tr>
<tr>
<td>High Level</td>
<td>&lt;500</td>
</tr>
<tr>
<td>Special Purpose</td>
<td>requires written permission from the CNSC</td>
</tr>
</tbody>
</table>

ALIs and appropriate laboratory classifications for some commonly used radioisotopes are given in Table VI-3.
TABLE VI-3. For commonly used radionuclides, ALI and maximum amount (MBq) to be used on the open bench according to the laboratory classifications

<table>
<thead>
<tr>
<th>ISOTOPE</th>
<th>ALI/MBq</th>
<th>Maximum amount (MBq) to use in Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BASIC</td>
</tr>
<tr>
<td>P-32</td>
<td>8</td>
<td>34.5</td>
</tr>
<tr>
<td>C-14</td>
<td>34</td>
<td>170</td>
</tr>
<tr>
<td>H-3</td>
<td>1000</td>
<td>5000</td>
</tr>
<tr>
<td>P-33</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>I-125</td>
<td>1</td>
<td>6.5</td>
</tr>
<tr>
<td>S-35</td>
<td>26</td>
<td>90</td>
</tr>
</tbody>
</table>

D. Posting of Signs and Labels

Posting requirements for rooms in which radioactive materials are used or stored vary depending on the type of source and usage. See TABLE IV.4 Posting Requirements for Radioactive Use Areas for specific requirements.

TABLE VI.4 – Posting requirements for radioactive use areas

<table>
<thead>
<tr>
<th>Laboratory Type</th>
<th>Current Permit</th>
<th>24-HOUR CONTACT INFORMATION</th>
<th>Radiation Warning Sign</th>
<th>“In Use” Sign</th>
<th>Safety Rules Poster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Source</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sealed Source</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Storage Area</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I. POSTING OF THE RADIOISOTOPE PERMIT

Any room that contains radionuclides in excess of 1 Exemption Quantity must have been approved by the Program Manager, Ionizing Radiation Safety and must be designated in a current radioisotope permit. Any enclosure, room, storage container, refrigerator or cupboard containing radioactive materials must be labeled as to the nature of the radioactive
materials and corresponding activities (See Table IV.1 for Exemption Quantities). To this end, the Radioisotope Permit must be posted on the outside of the door of all approved locations.

II. 24-HOUR CONTACT INFORMATION

All areas in which radioactive materials are used or stored must be labeled with the name and phone number of a person who can be contacted 24-hours a day in case of an accident or incident. Emergency Contact Telephone Numbers for the Program Manager, Ionizing Radiation Safety should be posted on the door of every room approved for radioisotope use.

III. THE RADIATION WARNING SIGN

If more than 100 EQ of radioactive materials are present, or there is a reasonable chance that a person may be exposed to an effective dose rate of greater than 25 μSv/hr (2.5 mR/hr), the room, vehicle or enclosure must be labeled with words: “DANGER – RADIATION- RAYONNEMENT” and the trefoil symbol in magenta or black on a yellow background (see Fig. VI-1).

IV. THE “IN USE” SIGN

The appropriate “IN USE” sign should be posted in the radiation work area when radioactive materials are in use and removed when the radioactive work is discontinued. See sample Fig. VI-2.
V. THE RADIOISOTOPE SAFETY POSTER

The appropriate lab rules poster issued by the CNSC entitled “RADIOISOTOPE SAFETY” must be posted inside labs using open sources in the radioisotope working area. For laboratories designated Basic, the orange Lab Rules poster entitled “RADIOISOTOPE SAFETY Basic Laboratories” is to be used. For those labs designated as Intermediate, the red Lab Rule poster entitled “RADIOISOTOPE SAFETY Intermediate Laboratories” is to be used. For laboratories designated as High Level, the poster must be approved by the CNSC.
VII. TYPES OF IONIZING RADIATION

Alpha, beta, gamma and X-ray radiations (neutrons are sometimes included, but are a bit special) are called ionizing radiations simply because they carry enough energy to cause ionizations during their interactions with matter (matter being any material, i.e., your body, the air, water). The efficiency with which it creates these ionizations depends upon the energy of the radiation emitted and the type of radiation: alpha, beta, gamma, X-ray or neutron. Note that normally, alpha, beta, X-rays and gamma rays cannot cause materials to become radioactive, while neutrons can activate or make radioactive previously inactive materials.

A. Alpha Emitters

Alpha emitters are positively charged helium nuclei. On a nuclear scale, they are quite large and travel for short distances, even in a medium of low density. As a result, they can be stopped by a sheet of paper or a thin layer of skin. They are, however, considerably more hazardous if ingested. Since they will deposit all of their energy within the body, they cause internal damage, particularly to the lungs if inhaled.

B. Beta Emitters

Beta particles are fast moving electrons which are emitted during certain type of radioactive decay. They are small compared to alpha particles. Low energy beta particles, such as those emitted by tritium (H-3), Carbon-14 (C-14), Sulphur-35 (S-35), and Phosphorus-33 (P-33) cannot even penetrate Plexiglas or glass, and likely will not penetrate the dead layer of the skin. High energy beta particles from Phosphorus-32 (P-32) require ¼ inch Plexiglas shielding to be stopped and may cause damage to the eye and skin. Consequently, users handling stock solutions of 50 MBq or more are requested to wear finger ring badges to monitor skin dose. Ingested, beta particles become more hazardous since practically all their emitted energy will be absorbed by the tissue.

C. Soft X-Rays and Gamma Emitters

X-rays and gamma radiation are forms of electromagnetic radiation (like visible light) and as such can behave as both a wave and a particle. While they represent the same physical phenomenon, the different appellation reflects different origin. X-rays emissions result from electronic transitions between inner atomic orbitals. Gamma rays originate from nuclear transitions from within the nucleus of the atom.

Both gamma rays and X-rays have a long range in air and hence, present an external hazard. Their ability to penetrate the human body is one of the reasons for their utility in medical diagnosis. However, since they can penetrate wood and concrete, shielding with a high density material is required. Normally, lead is used as an absorber either in the form of a lead "pig" container, lead brick or thin lead sheets. Internally, they can still cause damage, but to a much smaller degree, since they pass through the body. Examples of X-ray/gamma-rays emitters used at SFU are Iodine-125 (I-125) and Cobalt-57 (Co-57).
When working with gamma rays and X-rays, increasing the handling distance is a very simple and effective way to reduce body exposure. For high activity sources, where possible, remote handling tools should be used to increase the distance from the source (See Section X-B).

D. Neutrons

Neutrons have no charge and do not feel the electric charges of either the orbital electrons or of the nucleus; they lose their energy only by direct collision with the nucleus of the atom or by nuclear reaction. They are also difficult to detect directly. Concrete, water and paraffin are good shielding materials for this class of particles.
VIII. METHODS OF DETECTION

Gamma, beta and alpha radiation create ions in their interactions with matter and deposit some of their energy through complex processes. This energy transfer results in excitation, ion pair production, and/or other types of damage in the stopping medium, making it possible to detect these forms of ionizing radiation through various monitoring techniques. It is essential to be aware of the limitations of these monitoring techniques to avoid a false sense of security. The type of detection device to be used depends on the penetrating power and the efficiency of energy transfer (the linear energy transfer, LET) of the particular radiation.

At SFU, there are three principle modes of detection used:
- Solid scintillator contamination meter
- Geiger-Mueller contamination meter
- Swipe tests/liquid scintillation.

A. Solid Scintillators

Gamma radiation, being more penetrating and more difficult to stop than beta or alpha radiation, requires a detection device of higher density than a gas. Various materials, such as thallium activated sodium iodide crystal, when struck by radiation, convert part of the energy transferred to light. The number of photons thus generated is proportional to the energy deposited. The scintillator is optically coupled to a photomultiplier tube which generates a voltage pulse proportional to the number of photons detected (i.e., proportional to the energy deposited). The whole assembly is encapsulated in a light-proof casing. Other types of solid scintillators include silver activated zinc sulfide, organic crystal like anthracene, or organic scintillators imbedded in a polymer matrix (plastic scintillators).

B. Geiger-Müeller Tubes

Geiger-Müeller (GM) tubes are the best known and most popular radiation detectors; they are rugged, versatile and relatively inexpensive. In these devices, the detector material is a gas filling a conducting tube with a thin wire at its axis. A high voltage is applied between the tube and the wire. Somewhere on the tube is a thin window of low density material. Radiation penetrating the tube and interacting with the gas will create an avalanche of ion pairs which are collected on the wire, resulting in a voltage pulse. This pulse is processed into a signal, visual (deflection of a needle on a meter), audible (click in a speaker) or digital (for computer processing).

GM detectors are used primarily as contamination check instruments, to indicate the presence of a radiation field, but they cannot give direct information on the type or energy of the radiation. Radiation Safety also has one survey meter, which has internal compensation to allow measurement of exposure. Due to the nature of the detecting material (a gas), they are most effective with high LET radiation (beta radiation or low energy gamma) providing that the radiation has sufficient energy to penetrate the window. Table VIII-1 lists the GM detection efficiency for a selection of commonly used radioisotopes.
TABLE VIII-1. GM detector efficiency (detector equipped with a thin window 1–2 mg cm\(^{-2}\)).

<table>
<thead>
<tr>
<th>ISO TOPE</th>
<th>(E_{\beta\text{MAX}}) (MeV)</th>
<th>DETECTOR EFFICIENCY (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3</td>
<td>0.018</td>
<td>0</td>
</tr>
<tr>
<td>C-14</td>
<td>0.156</td>
<td>4 - 10</td>
</tr>
<tr>
<td>S-35</td>
<td>0.167</td>
<td>5 - 11</td>
</tr>
<tr>
<td>Ca-45</td>
<td>0.252</td>
<td>10 - 20</td>
</tr>
<tr>
<td>P-32</td>
<td>1.71</td>
<td>20 - 35</td>
</tr>
</tbody>
</table>

C. Swipe Tests

In this type of detection system, the detecting material is a scintillator in solution (“cocktail”). The surface to be tested is wiped over a standard size area (usually 100 cm\(^2\)) with a small piece of wet absorbent material (filter paper, cotton wool). The swab is stuffed into a glass or plastic scintillation vial to which a few milliliters of the cocktail is added. The radioactive emission "excites" the scintillation cocktail which in turn emits a burst of photons; the number of photons is proportional to the energy of the radiation emitted. The photons travel to a photomultiplier tube which again, generates a voltage pulse proportional to the number of photons detected. Efficiency of detection is high in this method since the radiation is emitted within the detecting material itself. In particular, it is the only way to detect weakly penetrating radiation such as the beta emission from tritium. More generally, it is the chosen method to detect low level, loose surface contamination in the work place.

D. Neutron Detection

Since neutrons are neutral, they cannot be detected directly. Instead, detection relies primarily on absorption of neutrons in helium-3, lithium-6 or boron-10. As the neutrons collide with these materials, they generate ionized particles, either protons or alpha particles, which have a high energy and can be detected. A Wide Energy Neutron Detector (Wendi-2) is suitable for neutron detection.

E. Comparison Of Detector Applications

In summary, the end window GM detector is the most versatile piece of monitoring equipment, however, its use is limited to materials which can penetrate its window and be stopped by the detecting material. For example, the 18 keV beta from tritium (H-3) will not be able to penetrate the window at all, the 156 keV from Carbon-14 (C-14) will barely be detected, while high energy gamma photons may go through the tube without significant interaction with the gas. It is not adequate for contamination checks. Table VIII-2 summarizes some relevant properties of various detectors and their applications.
TABLE VIII-2. Application of radiation detectors

<table>
<thead>
<tr>
<th>Detector</th>
<th>Radiation</th>
<th>Energy Range</th>
<th>Detection Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-M Tube</td>
<td>Alpha</td>
<td>above 3.5 MeV</td>
<td>low</td>
</tr>
<tr>
<td>G-M Tube</td>
<td>Beta and</td>
<td>above 70 keV</td>
<td>moderate</td>
</tr>
<tr>
<td></td>
<td>Electrons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-M Tube</td>
<td>Gamma</td>
<td>above 6 keV</td>
<td>low - near 1%</td>
</tr>
<tr>
<td>Organic Scintillator:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>anthracene, stilbene, in plastics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inorganic Scintillator:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZnS(Ag)</td>
<td>Gamma</td>
<td>above 4 MeV</td>
<td>high</td>
</tr>
<tr>
<td>Inorganic Scintillator:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaI(Tl) (25 mm dia x 25 mm thick)</td>
<td>Gamma</td>
<td>above 40 keV</td>
<td>moderate</td>
</tr>
<tr>
<td>Inorganic Scintillator:</td>
<td>Gamma</td>
<td>between 10 - 40 keV</td>
<td>moderate</td>
</tr>
<tr>
<td>NaI(Tl) (25 mm dia x 1 mm thick)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid Scintillation</td>
<td>Alpha, Beta,</td>
<td>0 - MeV range</td>
<td>varies with</td>
</tr>
<tr>
<td></td>
<td>Gamma</td>
<td></td>
<td>radiation energy</td>
</tr>
<tr>
<td>Wide Energy Neutron Detector</td>
<td>Neutrons</td>
<td>Thermal (25 MeV) to 5 GeV range</td>
<td></td>
</tr>
<tr>
<td>(Wendi-2)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F. Monitor Maintenance

At SFU, we have two types of monitors: survey meters and contamination meters. Survey meters measure dose rate or amount of dose to a person per unit time. The units of measurement are mR/hr or mSv/hr. Survey meters must be calibrated annually by a certified technician. Contamination monitors measure activity per unit time. The units are cpm/min. Contamination meters are difficult to calibrate since the efficiency for detection of activity will vary with the energy of the radioisotope being measured. Contamination meters undergo an annual operational check carried out by the Radiation Safety staff. Several meters are sent to a CNSC certified technician for calibration for response to Cs-137. These calibrated monitors are identified by coloured label tape on the handle and are strategically located at various sites across the campus.

Battery checks should be performed on all monitors prior to use each time that you turn on the monitor.
IX. CONTAMINATION CHECKS

A. Monitoring Requirements For Sealed Sources

When using sealed sources, the radioactive work area must be assessed on a routine basis for contamination. It is preferable when working with gamma and X-ray emitters to leave the GM in the working area with the monitor on. Shielding shall be provided to ensure that workers are not exposed to radiation levels in excess of 25 µSv hr⁻¹ (2.5 mRem hr⁻¹); in most cases, workers should be shielded such that fields do not exceed 2.5 µSv hr⁻¹ (0.25 mRem hr⁻¹). Sealed sources with an activity greater than 50 MBq are checked twice annually for leakage by Radiation Safety staff (see Appendix III for Leak Testing Protocol).

B. Monitoring Requirements for Open Sources

It is preferable when working with high energy beta, gamma or X-ray emitters to leave the contamination meter in the working area with the monitor on. In addition, routine swipe tests are required at SFU when using open sources. In particular, in authorized locations swipe tests of the work area must be done at minimum on a weekly basis. Weeks during which work with radioactive open sources is carried out are to be noted on the yearly calendar included in the swipe test log book. Users must relate the activity found on the swipe test to the criteria laid out in the University’s radioisotope license. For information on the length of time required to produce results with the proper accuracy, see Appendix VI.

Table IX-1. Allowable non-fixed contamination for Class A, B, and C isotopes

<table>
<thead>
<tr>
<th>Sample Isotopes</th>
<th>Areas where unsealed nuclear substances are used or stored (Bq cm⁻²)</th>
<th>All other areas (Bq cm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLASS A ISOTOPES long lived alpha emitters and daughters</td>
<td>Co-56, Cs-137, Po-210, Na-22, Pu-239</td>
<td>3</td>
</tr>
<tr>
<td>CLASS B ISOTOPES long lived beta or gamma emitters</td>
<td>Sr-90, I-131</td>
<td>30</td>
</tr>
<tr>
<td>CLASS C ISOTOPES short lived beta or gamma emitters</td>
<td>C-14, Co-57, H-3, P-32, Ca-45, Cd-109, I-125, P-33, Cl-36, Fe-55, Ni-63, S-35</td>
<td>300</td>
</tr>
</tbody>
</table>
The amount of removable contamination permitted depends on the isotope in use, its halflife, the nature of the emission and whether the area is one in which isotopes are used or stored or other areas.

Table IX-1 gives the allowable non-fixed contamination for Class A, Class B and Class C isotopes in areas where nuclear substances are used or stored and in all other areas. **Note that the area reported in the swipe test record shall not exceed 100 cm^2** (see also Table IX-4 for approximate surface area of common items.). A radiation field due to fixed contamination must not exceed 0.5 µSv/hr at a distance of 0.5 m. In the worst case scenario, an individual who spent an entire working day at a distance of 0.5 m from a source with a dose rate of 0.5uSv/hr, would receive a yearly integrated dose of 2000 x 0.5 = 1000 uSv/year = 1 mSv/Year (assuming a 2000 hour yearly work load). That is, the individual would receive the maximum yearly allowable occupational dose.

### C. Calculation of Maximum Permissible Contamination for Swipe Tests

This section describes how to convert the licence criteria for allowable non-fixed contamination shown in Table IX-1 to practical units (cpm/cm^2) taking into account the efficiency of the liquid scintillation counter shown in Table IX-2, and the efficiency of the swipe to remove non-fixed contamination. On the following page is a sample calculation, using C-14 as the isotope being measured, which shows how to derive maximum permissible contamination values for swipe tests from the licence criteria and the liquid scintillation counter efficiency.

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Typical Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3</td>
<td>50%</td>
</tr>
<tr>
<td>I-125</td>
<td>58%</td>
</tr>
<tr>
<td>Co-57</td>
<td>80%</td>
</tr>
<tr>
<td>Ni-63</td>
<td>85%</td>
</tr>
<tr>
<td>C-14, S-35</td>
<td>90%</td>
</tr>
<tr>
<td>I-131, Cd-109</td>
<td>95%</td>
</tr>
<tr>
<td>Pu-239</td>
<td>98%</td>
</tr>
<tr>
<td>P-32, P-33, Na-22, Co-60, Cs-137, Po-210, Ca-45, Cl-36</td>
<td>100%</td>
</tr>
</tbody>
</table>

For use of C-14 in areas of use or storage, the criteria is 300 Bq cm^2. Therefore the criteria, expressed in disintegrations per minute (dpm) is derived as follows:

\[
300 \text{ Bq cm}^2 = 300 \text{ dps cm}^2 \times 60 \text{ s min}^{-1} = 18000 \text{ dpm cm}^2
\]
To obtain the criteria expressed in cpm (counts per minute) which is the quantity provided by the measuring instrument, the dpm cm\(^{-2}\) is multiplied by the detector efficiency and by the swipe efficiency, i.e:

\[
cpm \text{ cm}^{-2} = (\text{dpm cm}^{-2}) \times (\text{LSC efficiency for particular isotope}) \times (\text{swipe efficiency})
\]

Example of C-14:
LSC efficiency \(\approx 90\%\) (see Table IX-2 for LSC efficiency for selected radioisotopes); typically one assumes a 10\% swipe efficiency. Then:

\[
\text{Allowable contamination} = 18000 \text{ dpm cm}^{-2} \\
\approx 18000 \text{ dpm cm}^{-2} \times 90\% \times 10\% \approx 1620 \text{ cpm cm}^{-2}
\]

Table IX-3 compiles the results of these calculations for selected isotopes used at SFU. For ease, the numbers in Table IX-3 have been rounded off, erring on the side of caution, including the most restrictive case of a Class A isotope. These values, summarized in the last row of Table IX-3 represent at SFU the recommended levels of removable surface contamination above which the surface is to be considered contaminated.

Table IX-3 – Approximate Liquid Scintillation Counting readings corresponding to maximum permissible removable surface contamination for selected radioisotopes.

<table>
<thead>
<tr>
<th>Isotopes</th>
<th>Areas of Use/Storage</th>
<th>Other Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3</td>
<td>540</td>
<td>54</td>
</tr>
<tr>
<td>C-14</td>
<td>1620</td>
<td>162</td>
</tr>
<tr>
<td>Na-22, Cs-137, Co-60, U isotopes</td>
<td>18</td>
<td>1.8</td>
</tr>
<tr>
<td>P-32, P-33</td>
<td>1800</td>
<td>180</td>
</tr>
<tr>
<td>Co-57</td>
<td>180</td>
<td>18</td>
</tr>
<tr>
<td>I-125</td>
<td>1044</td>
<td>104</td>
</tr>
<tr>
<td>Pu-239</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Sr-90, I-131</td>
<td>171</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**The swipe efficiency is assumed to be 10\%.**
Based on the values determined in Table IX-3 and for ease of use, Radiation Safety has established the recommended values for maximum permissible removable contamination in Table IX-4.

<p>| Table IX-4 – SFU Radiation Safety Recommendation for maximum permissible removable surface contamination |
|-------------------------------------------------|-------------------------------------------------|-----------------|------------------|</p>
<table>
<thead>
<tr>
<th>Maximum net cpm cm$^{-2}$ (Net cpm = Gross cpm – background)</th>
<th>All Isotopes</th>
<th>Area of Use/Storage</th>
<th>All Other Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Isotopes</td>
<td>10</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

If contamination in excess of the values in Table IX-4 is found, the item should be decontaminated as soon as possible. If the floor or equipment in an area other than one where isotopes are used or stored, the equipment or area must be clearly delineated or marked to show radioactive contamination.

Following decontamination, items or areas must be reswiped and the new swipe test values entered in the Swipe Test log or record. The Geiger counter with the GM probe is not an acceptable method of detecting contamination for these weekly checks: the Geiger counter should be used while handling radioactive materials and for daily contamination checks. Note that contaminated bench paper is to be discarded in its entirety; it is not acceptable to cut out only the contaminated areas.

For reference and to express the results of swipe checks into cpm per cm, Table IX-5 below gives approximate surface areas of common items used in a radioisotope laboratory.

<p>| Table IX-5. Approximate surface area of common items to estimate surface contamination from swipe test activity readings. |
|-------------------------------------------------|-------------------------------------------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Item</th>
<th>Area in cm$^2$</th>
<th>Area to use for calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>pipetter</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>1 floor tile</td>
<td>900</td>
<td>100</td>
</tr>
<tr>
<td>large tongs</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>large shield</td>
<td>2500</td>
<td>100</td>
</tr>
<tr>
<td>small shield</td>
<td>900</td>
<td>100</td>
</tr>
<tr>
<td>gelbox and tray</td>
<td>900</td>
<td>100</td>
</tr>
</tbody>
</table>
D. Record Keeping of Swipe Tests

A numerical record of the results must be entered in the contamination log in the form of counts per surface area swiped. It is not acceptable to record swipe test results as “background” or “no contamination found.” These records may not be discarded without permission of the CNSC. Weeks in which radioactive work with open sources is carried out are to be noted on the yearly calendar included in the weekly swipe test log.

E. Sample Swipe Test Record Form

There are two options for this form: one records results in net cpm/cm² and the other Bq/cm²; see http://www.sfu.ca/srs/ehs/rso/swipe-tests.html for forms which can be downloaded or Figures IX-1 and IX-2 on the following pages.
Fig. IX-1. Swipe Test Record with units of cpm/cm².

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Room Number</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Date (include year)</th>
<th>Swipe Test Location</th>
<th>Swipe Area (Max. 100 cm²)</th>
<th>Net cpm</th>
<th>cpm/cm² (after cleaning)</th>
<th>Initials</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
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Allowable readings:
- in areas where nuclear substances are used or stored: cpm/cm² < 10
- in all other areas: cpm/cm² < 1
Fig. IX-2. Swipe Test Record with units of Bq/cm².

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Room Number</th>
<th>Year</th>
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<tbody>
<tr>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Date (include year)</th>
<th>Swipe Test Location</th>
<th>Wipe Area (Max. 100 cm²)</th>
<th>Net cpm</th>
<th>Bq/cm²</th>
<th>Bq/cm² (after cleaning)</th>
<th>Initials</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

Bq/cm² = \( \frac{\text{Net cpm}}{6 \times \text{Swipe Size (cm²)}} \) must be < 3Bq/cm² in areas of use/storage < 0.3 Bq/cm² in all other areas
F. Contamination Control

To reduce the chances of contamination:

- review the experimental protocol prior to using radioactive materials,
- streamline handling,
- remove unnecessary equipment from the radioactive area,
- use double containment (i.e. place radioactive materials in a secondary container),
- continuously monitor the work area, gloves and labcoats if feasible,
- when working with volatile radionuclides, all handling of such material must be done in the fume hood,
- keep in mind that some radionuclides may have volatile decomposition products, as is the case with S-35 methionine, which may require special handling procedures.
- wear gloves only during handling; contaminated gloves will contaminate anything else you touch.

It is a policy at SFU that one glove may be worn, if necessary, outside the lab when carrying hazardous materials. However, caution is required to ensure that you use the non-gloved hand to open doors and other enclosures.

For contamination control it is advised not to wear labcoats outside labs in hallways.
X. MINIMIZATION OF EXPOSURE

There are three basic principles to keep in mind when working with radiation in order to minimize one’s exposure: time, distance, and shielding. These factors should be used for effective protection of users of radioisotopes.

A. Minimize Exposure Time

Experiments must be carefully planned in order to minimize the time of exposure. “Dry” runs in which no active materials are used should be performed to master the particular technique. Attention should be given to ensure that active stock solutions be accessed a minimum number of times. For instance, it may be more advantageous to withdraw one aliquot of 300 kBq from the main source and divide it further into three samples than to withdraw a 100 kBq aliquot from the same source on three separate occasions, risking exposure to the source each time.

B. Increase Distance from Source

Increasing distance is one of the easiest and least expensive methods of minimizing exposure. It is also very effective, especially for alpha and beta radiation which have a short range in air. Although gamma and X-rays have longer ranges, exposure can still be greatly minimized by increasing body distance from the source.

The relationship between source and point of interest is expressed by the inverse square law:

$$\frac{I}{I_0} = \frac{D_0^2}{D^2}$$

Where $I_0$ is the original intensity, $D_0$ the original distance, $I$ the "new" intensity $D$ the new distance.

Example: What is the intensity of radiation from a gamma source at 6 m if a reading taken at 0.5 m is 600 mR hr⁻¹?

In this example, $I_0 = 600$ mR hr⁻¹, $D_0 = 0.6$ m, and $D = 6$ m. Solving for $I$:

$$I = I_0 \times \frac{D_0^2}{D^2}$$

$$I = 6 \text{ mR hr}^{-1}$$

This example assumes that the absorption through air is negligible.
NOTE:
The inverse-square law does not apply for low and medium energy beta emitters. For example you could measure the beta radiation field at one meter from 37 MBq of I-131 and note that it is 4 $\mu$Gy hr$^{-1}$. Applying the inverse square law you would calculate 4 mGy hr$^{-1}$ at 10 cm and 400 mGy hr$^{-1}$ at 1 cm. The actual fields are more than a factor of ten greater than this. The inverse square law does not take into account the air absorption of low and medium energy betas.

C. Use Shielding

Shielding requirements can be determined by referring to the Half-Value Layer (HVL) and Tenth-Value Layer (TVL). The HVL and TVL are that amount of absorber which reduce the original intensity of the radiation by one-half or one-tenth respectively. These values are available in health physics manuals.

Shielding shall be provided to ensure that workers are not exposed to radiation levels in excess of 25 $\mu$Sv hr$^{-1}$ (2.5 mRem hr$^{-1}$); in most cases, workers should be shielded such that fields do not exceed 2.5 $\mu$Sv hr$^{-1}$ (0.25 mRem hr$^{-1}$).

In any situation requiring shielding, consideration should be given to the 4-$\pi$ (all directions) solid angle geometry of radioactive emission; this may necessitate shielding the back of a hood or bench area to protect individuals in adjoining rooms, or shielding the bench "floor" to reduce exposure to the lower torso and legs.

GAMMA EMITTERS.

For gamma emitters and X-rays the ideal absorber, because of its high density, is lead. Its major drawback is a low melting point, which in the case of fire, would leave the source exposed. Additionally, lead residue is toxic if ingested or inhaled. Other absorbers are concrete, steel, iron, depleted uranium and fan steel. The most commonly used are lead and concrete. When working with lead shielding, it is important that the bench be strong enough to support the weight of the bricks and gloves should be worn to prevent transfer of lead to the hands.

BETA EMITTERS

Beta emitters have limited range in air and in the majority of cases the glass container or the liquid itself will absorb most of the beta particles emitted. Higher energy betas such as those emitted by P-32 with an $E_{\beta\text{max}}$ of 1.7 MeV have a maximum range of 6 m in air. For these "hard" betas shielding becomes essential.

When shielding against beta particles, "Bremsstrahlung" emissions must also be considered. Bremsstrahlung radiation is produced during the interaction of electrons (beta particles) with the medium they traverse. Bremsstrahlung intensity and energy increases with the atomic number of the absorber material. For this reason low density materials such as glass or Plexiglas are the ideal absorbers for high energy beta particles; lead should only be used as a secondary shield for high energy beta radiation. At SFU we expect P-32 us-
ers to do their major handling behind Plexiglas shields and to store their contaminated waste in Plexiglas or glass containers with a lid.

Table IX-5. Approximate surface area of common items to estimate surface contamination from swipe test activity readings.

<table>
<thead>
<tr>
<th>Item</th>
<th>Area in cm²</th>
<th>Area to use for calculations</th>
</tr>
</thead>
</table>

Table X-1 Shielding for Some Commonly Used Radionuclides

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Shielding Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3 (Tritium)</td>
<td>None</td>
</tr>
<tr>
<td>C-14, S-35, Ca-45</td>
<td>Plexiglas if detectable with the GM</td>
</tr>
<tr>
<td>P-32, Sr-90</td>
<td>Plexiglas</td>
</tr>
<tr>
<td>I-125</td>
<td>Lead sheeting</td>
</tr>
<tr>
<td>Co-60, Na-22</td>
<td>Lead Bricks</td>
</tr>
</tbody>
</table>
XI. TRACKING RADIOACTIVE MATERIALS

A. Receipt of Radioactive Materials

Tracking of radioactive materials on campus is ‘cradle-to-grave;’ all materials must be accounted for from the moment they arrive on campus until they leave as waste or are transferred to another site.

All incoming items containing radioactive materials arrive at ‘Science Receiving’. These items are then transferred to the Radiation Safety Technician (RST). At SFU, only the RST or a trained substitute opens radioactive shipments. The procedure for receiving radioactive materials is as follows:

- Perform all manipulations wearing a lab coat and disposable gloves;
- If material is volatile, place the package in the fume hood. If the package contains high energy beta, gamma or X-ray emitters, place the package behind appropriate shielding before proceeding;
- Swipe test the external surface of the package for contamination;
- Check the package contents for possible damage and if damage is discovered, isolate the package to prevent contamination;
- Remove any seals or plugs to the vial;
- Swipe test the interior surfaces of the original package, the vial and the vial holder (pig), if present;
- If contamination is found on the external packaging, consult the waste regulations to determine if packaging should be stored for decay or disposed; if no contamination is found on the outside and inside of the box, deface any radioactive materials print/sign on box;
- If contamination is found on the vial or vial holder, decontaminate by spraying paper towels with cleaning solution and wiping down the surfaces. Swipe the surfaces again. If contamination persists, repeat decontamination followed by swipe testing until the contamination levels fall within the levels recommended in Table IX-3 of Section IX Contamination Checks;
- Record swipe test results, batch number, purchase order number, volume or weight, activity, half-life, catalogue number, vendor, permit holder who ordered the material, destination room number, date ordered and reference date. Issue a unique identifying sticker and decal number for each item;
- Enter the item in the Radiation Safety Inventory Data Base;
- Prepare an Inventory Sheet for the vial(s) and deliver the vial(s) to the user.

If irregularities are noted in the shipping documents, labeling, contamination on the outside of the package or a damaged package or package contents, contact the RST or the Program Manager, Ionizing Radiation Safety with the details.
B. Inventory Control

Each open source is accompanied by an inventory record sheet. Isotope users are responsible for:

- maintaining an ongoing record of usage of each source,
- tracking each aliquot removed by weight or volume from the original vial,
- estimating the activity delivered to each waste stream,
- noting the date on which the empty source vial is returned to the Hot Lab.

Records of use must be readily accessible for inspections and may not be discarded without prior approval from Radiation Safety staff. See sample Inventory Sheet in Fig. XII-1 that follows. In the case of sealed sources only an inventory number is issued.

C. Tracking Protocol

The SFU tracking protocol is displayed as a block diagram chart in Fig. XII-2, which follows.
Fig. XI-1. Sample inventory sheet.

SIMON FRASER UNIVERSITY
Radioisotope Usage

<table>
<thead>
<tr>
<th>Code:</th>
<th>Form:</th>
<th>Permit Holder:</th>
<th>Bat. Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>Ref. Date:</td>
<td>Date Ord'd:</td>
<td>PO Number:</td>
</tr>
<tr>
<td>Vendor:</td>
<td>Half-life:</td>
<td>Amount (MBq):</td>
<td>Cat. Number:</td>
</tr>
<tr>
<td>Room:</td>
<td></td>
<td>Volume (µl):</td>
<td>Location:</td>
</tr>
</tbody>
</table>

Date vial sent to Hotlab

<table>
<thead>
<tr>
<th>SOURCE USAGE (UNIT = )</th>
<th>WASTE BREAKDOWN (UNIT= )</th>
<th>PRODUCT INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
<td>USER</td>
<td>AMOUNT USED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REMARKS:
Radiation Safety Technician (RST) reviews and authorizes orders of nuclear materials.

Radioactive Materials received in Science Stores/Receiving

Material transferred to Radiation Safety Technician (RST) in Hot Lab B7249

1. Package swipe tested
2. Unique inventory # assigned
3. Inventory sheet prepared

Vial/source transferred to user with inventory sheet

User notes waste breakdown on inventory sheet

Aqueous waste to B7249

- Stored for decay, then disposed to sewer

- Activity and volume disposed recorded by RST

Organic liquid waste to B7249

- Diluted to <1 EQ per liter and sent for incineration via commercial carrier

Low level solid waste to B7249

- Checked by RST then disposed as non-radioactive garbage

High level solid waste to B7249

- Stored for 10 half-lives then disposed as non-radioactive waste or shipped for disposal

- Activity and volume recorded by RST

Animal carcasses and feces to B7249

- Sent for incineration

- Activity and weight disposed recorded by RST

Low level animal bedding to B7249

- To municipal garbage

- Activity and weight disposed recorded by RST

Radioactive Materials received in Science Stores/Receiving

To sewer

Empty vial returned to RST, to Hot Lab

User notes date of return on inventory sheet

Activity and volume disposed recorded by RST

Activity and volume released to carrier recorded by RST

Activity and weight disposed recorded by RST
XII. HANDLING OF RADIOACTIVE WASTES

The disposal of all radioactive waste is regulated by the CNSC, which specifies that a strict accounting be made of all radioactive waste generated. The CNSC has also determined the maximum amount of each isotope (expressed in Exemption Quantities) which may be released to the atmosphere, the municipal garbage, or the water system. These values are summarized below in Table XII-1.

Table XII-1. Accepted Release Limits for Commonly Used Radioisotopes

<table>
<thead>
<tr>
<th>Isotope</th>
<th>EQ (MBq)</th>
<th>Solids to Municipal Garbage (MBq/Kg)</th>
<th>Aqueous waste to Municipal Sewer System (MBq/year/building)</th>
<th>Gaseous waste to atmosphere (kBq/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-14</td>
<td>10</td>
<td>3.7</td>
<td>10,000</td>
<td>-</td>
</tr>
<tr>
<td>P-32</td>
<td>0.01</td>
<td>0.37</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>H-3</td>
<td>1000</td>
<td>37</td>
<td>1,000,000</td>
<td>37</td>
</tr>
<tr>
<td>I-125</td>
<td>1</td>
<td>0.037</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>P-33</td>
<td>100</td>
<td>1</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>S-35</td>
<td>100</td>
<td>0.37</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>Co-57</td>
<td>1</td>
<td>0.37</td>
<td>1000</td>
<td>-</td>
</tr>
</tbody>
</table>

At SFU, radioactive waste disposal is controlled by the Radiation Safety Technician (RST). In general, users are required to

- segregate radioactive waste by isotope;
- segregate waste by waste type (organic liquid, aqueous liquid, low level solid, high level solid);
- determine the activity of the waste;
- label each waste container with a waste tag, noting waste type, isotope, activity, room of origin, permit holder and date to facilitate handling. See sample waste tag in Fig. XII-1.
- enter the identification number (ID#) of the waste tag on the inventory sheet to ensure tracking of any waste to its source vial.
- transfer suitably labeled and packaged wastes to the Hot Lab for further processing.

Detailed protocols for waste analysis and handling can be found in Table XII-2. This table has links which show appropriate containment and packaging for various forms of radioactive waste. If you wish to view the pictures of waste containment and packaging in: http://www.sfu.ca/srs/ehs/rs/research-safety/rso/radioactive-waste-handling.html and click on individual waste designations for a visual representation.
Waste which is in excess of exemption quantities may be stored for decay if the half-life of
the material is less than 2 years. The length of storage required is in the range of 7 to 10
half-lives. After 7 half-lives the activity of any radionuclide is reduced to less than 1% of its
initial value. These wastes must be monitored prior to disposal. Waste containing materi-
als with half-lives in excess of two years is currently stored on campus, but may have to be
sent off-campus for disposal. It is important that only contaminated waste be sent to stor-
age. Space is limited and should not be used to store trace contamination or uncontami-
nated rubbish for years.

All radioactive waste generated must be clearly labeled as to isotope, approximate activity,
room number of origin, date, and permit holder using tags provided. See Fig. XII-1, Sam-
ple Radioactive Waste Tag.

Fig. XII-1. Sample Radioactive Waste Tag.
Table XII-2. Radioactive waste handling chart.

<table>
<thead>
<tr>
<th>DESIGNATION</th>
<th>EXAMPLES</th>
<th>CRITERIA</th>
<th>CONTAINMENT</th>
<th>DISPOSAL PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLID - Low level</td>
<td>gloves, paper toweling, empty scintillation vials</td>
<td>for H-3, C-14, P-33, S-35: possibly contaminated but not likely for P-32 and I-125: &lt;100 cpm measured with the Geiger-Counter</td>
<td>Specially marked foot operated garbage cans lined with plastic bags</td>
<td>Remove plastic bag, complete waste tag and tie to bag, record waste tag number on inventory sheet(s) and transfer bag to SSC-B7249 Hot Lab</td>
</tr>
<tr>
<td>SOLID - High Level</td>
<td>pipette tips, eppendorf holders, contaminated bench paper</td>
<td>for H-3, C-14, P-33, S-35: anything which has been in intimate contact with radiotrace for P-32 and I-125: &gt;100 cpm above background measured with the G.M.</td>
<td>for H-3, C-14, P-33, S-35: beaker lined with plastic bag for P-32 and I-125: shielded box (plexiglass or lead) lined with a plastic bag</td>
<td>Remove plastic bag, complete waste tag and tie to bag, record waste tag number on inventory sheet(s) and transfer bag to SSC-B7249 Hot Lab. In the case of P-32 and I-125, transport with appropriate shielding</td>
</tr>
<tr>
<td>SOLID – Sharps</td>
<td>syringes, needles, scalpel blades, razor blades</td>
<td></td>
<td>Radioactive Sharps Container available from the Hot Lab</td>
<td>Label with waste tag, record activity on inventory sheet and take to SSC-B7249 Hot Lab</td>
</tr>
<tr>
<td>SOLID – glass</td>
<td>Pasteur pipettes, test tubes, broken glass</td>
<td></td>
<td>Wide mouthed plastic jugs with secured lid, or by prior arrangement, a plastic lined box, or THICK plastic bags</td>
<td>Label with waste tag, record activity on inventory sheet and take to SSC-B7249 Hot Lab</td>
</tr>
<tr>
<td>SOLID - Animal Materials</td>
<td>animal excrement, carcasses, animal tissue or tissue digests</td>
<td>H-3 &lt; 37 MBq/kg C-14 &lt; 3.7 MBq/kg P-33 &lt; 0.37 MBq/kg S-35 &lt; 0.037 MBq/kg P-32 &lt; 0.37 MBq/kg I-125 &lt; 0.037 MBq/kg</td>
<td>Store in freezer until disposal is arranged with Radiation Safety Technician</td>
<td>Wrap in plastic bag, tag, record activity on inventory sheet, and take to SSC-B7249 Hot Lab with prior arrangement (tel: 2-3506)</td>
</tr>
</tbody>
</table>
### Table XII-2. Radioactive waste handling chart. (continued)

<table>
<thead>
<tr>
<th>DESIGNATION</th>
<th>EXAMPLES</th>
<th>CRITERIA</th>
<th>CONTAINMENT</th>
<th>DISPOSAL PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQUEOUS LIQUID - Low Level (water based)</td>
<td>sequencing buffer, water soluble materials</td>
<td>H-3 &lt; 1,000 cpm/ml, C-14 &lt; 200 cpm/ml, P-32 &lt; 200 cpm/ml</td>
<td>Empty plastic bottle or jug with secure lid, NO GLASS.</td>
<td>Remove 1 ml sample of liquid and count on Liquid Scintillation Counter. Record activity on tag and inventory sheet. Place bottle in plastic bag and seal. Transfer to SSC-B7249 Hot Lab.</td>
</tr>
<tr>
<td>AQUEOUS LIQUID - High Level (water based)</td>
<td>reaction products which are water soluble</td>
<td>H-3 &gt; 1,000 cpm/ml, C-14 &gt; 200 cpm/ml, P-32 &gt; 200 dpm/ml, P-33 all aqueous waste, S-35 all aqueous waste, I-125 all aqueous waste</td>
<td>Empty plastic bottle or jug with secure lid, NO GLASS.</td>
<td>Remove 1 ml sample of liquid and count on Liquid Scintillation Counter. Record activity on tag and inventory sheet. Place bottle in plastic bag and seal. Transfer to SSC-B7249 Hot Lab.</td>
</tr>
<tr>
<td>ORGANIC LIQUID</td>
<td>scintillation liquid, solvent based reaction materials, chlorinated materials, toxic materials, water insoluble materials</td>
<td></td>
<td>Empty plastic bottle or jug with secure lid, NO GLASS.</td>
<td>Remove 1 ml sample of liquid and count on Liquid Scintillation Counter. Record activity on tag and inventory sheet. Place bottle in plastic bag and seal. Transfer to SSC-B7249 Hot Lab.</td>
</tr>
<tr>
<td>RADIOACTIVE and BIOHAZARDOUS</td>
<td>radioactive blood, bacteria viruses, primate body fluids</td>
<td>Biohazard Classification Risk Group 1 or 2.</td>
<td>Contact Environmental Health and Safety at 5728 for procedures before packaging waste.</td>
<td>Do NOT autoclave radioactive biohazardous materials. Label container with waste tag and transfer to SSC-B7249 Hot Lab.</td>
</tr>
<tr>
<td>RADIOACTIVE SHARPS and BIOHAZARDOUS</td>
<td>radioactive and biohazardous needles, syringes, scalpel blades, razor blades</td>
<td>Biohazard Classification Risk Group 1 or 2.</td>
<td>Designated Red Biohazardous Sharps Container available from Science Stores. Contact Environmental Health and Safety at 5728 for procedures before packaging waste.</td>
<td>Do NOT autoclave radioactive biohazardous materials. Label container with waste tag and transfer to SSC-B7249 Hot Lab.</td>
</tr>
</tbody>
</table>
XIII. PERSONAL MONITORING PROGRAM

A. Personal Monitoring

EXTERNAL MONITORING

External Monitoring is accomplished using Optically Stimulated Luminescent (OSLs) badges, also called radiation badges or personal dosimeters. See Table XIII-1 to determine if your work requires that you wear a badge. OSLs can be used to monitor the whole body potential exposure to stronger beta or gamma radiation. For the exposure to radiation of extremities, ie. fingers Thermoluminescent Dosimeters (TLDs) are used. Since the personal dosimeters are worn for 3–4 months at a time prior for evaluation of exposure, there can be a substantial time delay in assessing exposures. If immediate information is required, as is the case in work undertaken in high radiation fields, a direct readout, pocket dosimeter will be issued.

Table XIII-1. Badge Requirements

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Whole Body TLD</th>
<th>Extremity TLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3, C-14, S-35, Ca-45, Fe-55, P-33</td>
<td>Not required</td>
<td>Not required</td>
</tr>
<tr>
<td>P-32</td>
<td>Not required</td>
<td>Required if activity &gt; 50 MBq</td>
</tr>
<tr>
<td>Gamma and X-Ray emitters</td>
<td>Required for any activity</td>
<td>Required if activity &gt; 50 MBq</td>
</tr>
<tr>
<td>X-ray Generating Equipment</td>
<td>Required</td>
<td>Not required</td>
</tr>
</tbody>
</table>

INTERNAL MONITORING

Internal monitoring is necessary when volatile radioisotopes are used or accidentally ingested. This form of monitoring is referred to as "bioassay". Useful methods of bioassay are organ counting, urine assay, saliva swabs, serum and fecal counts.

THYROID BIOASSAY

Individuals using radioiodines may be required to undergo thyroid bioassays according to the criteria in Table XIII–2 below. Individuals requiring bioassay are required to report to the RST in the Hot Lab or the Program Manager, Ionizing Radiation Safety to undergo a thyroid check prior to initiating work with radioiodines and then again during the interval 24
hours – five days following an experiment involving an iodination. Thyroid bioassays must be undertaken using the Sodium Iodide (NaI) probe in the Hot Lab (B7249) specifically calibrated for this purpose. Results showing intake in excess of 1 kBq (60,000 cpm) must be reported to the RSO for investigation. The counting system dedicated to thyroid measurement of iodine intake is preset to give a Minimum Detectable Amount (MDA) of 300 Bq (+/- 20%).

Table XIII-2. Bioassay Requirements for Radioiodine Use

<table>
<thead>
<tr>
<th>Location of Use</th>
<th>Activity of Radioiodine Used within a 24-Hour Period and Requiring Bioassay (MBq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open room</td>
<td>2 MBq</td>
</tr>
<tr>
<td>Fume hood</td>
<td>200 MBq</td>
</tr>
<tr>
<td>Glove box</td>
<td>20,000 MBq</td>
</tr>
<tr>
<td>Spill of volatile radio-iodines</td>
<td>2 MBq</td>
</tr>
<tr>
<td>External radioiodine contamination detected</td>
<td>any amount</td>
</tr>
</tbody>
</table>

B. Personal Exposure Records

Radiation Safety staff maintain all records of internal and external monitoring in conjunction with the National Dosimetry Service in Ottawa. A cumulative record of exposure for each individual wearing a TLD is maintained in Ottawa over the work period of the user. These records are open to anyone wishing to see them. Contact the RST for further information.

C. Nuclear Energy Workers (NEW)

A nuclear energy worker (NEW) is by definition, “a person who is required, in the course of the person's business or occupation in connection with a nuclear substance or nuclear facility, to perform duties in such circumstances that there is a reasonable probability that the person may receive a dose of radiation that is greater than the prescribed limit for the general public” (Nuclear Safety and Control Act).

The NEW classification is made by the Program Manager, Ionizing Radiation Safety. According to the Radiation Protection Regulations, every licensee shall inform each nuclear energy worker, in writing,

1. a) that he or she is a nuclear energy worker;
   b) of the risks associated with radiation to which the worker may be exposed in the course of his or her work, including for women, the risks associated with the exposure of embryos and fetuses to radiation;
c) of the applicable effective dose limits and equivalent dose limits
d) of the worker’s radiation dose levels.

2. The licensee shall also inform each female nuclear energy worker, in writing of the rights and obligations of a pregnant NEW and the effective dose limits.

3. Radiation Safety staff must obtain from each NEW written acknowledgement that the NEW has received the above information (see Appendix VIII for Notification of Nuclear Energy Worker Status form).

D. Maximum Permissible Doses

The maximum permissible occupational doses are listed in Table XIII-3.

Table XIII-3. Maximum permissible doses

<table>
<thead>
<tr>
<th>Target Organ or Tissue</th>
<th>Nuclear Energy Workers</th>
<th>General Public</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mSv y⁻¹</td>
<td>Rem y⁻¹</td>
</tr>
<tr>
<td>Whole Body</td>
<td>50 or &lt; 100 over 5 years</td>
<td>5 or &lt; 10 over 5 years</td>
</tr>
<tr>
<td>Skin</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>Lens of eye</td>
<td>150</td>
<td>15</td>
</tr>
<tr>
<td>Hands and feet</td>
<td>500</td>
<td>50</td>
</tr>
</tbody>
</table>

E. Pregnancy and Breast Feeding while Working with Radioisotopes

All women who are pregnant or who are breastfeeding and who work with radioactive materials must inform the University in writing. The effective dose to a pregnant nuclear energy worker (NEW) must not exceed 4 mSv for the balance of the pregnancy. The dose to a female worker who is breast-feeding must be such that the dose to the breast-fed infant does not exceed the whole body dose to a member of the general public, that is, 1 mSv/year.

In addition to the regulations of the CNSC, the regulations of the provincial WorkSafeBC include some aspects of radioactive work. In particular, WorkSafeBC regulations stipulate that:

- the effective radiation dose to a pregnant woman using radioisotopes is limited to 4 mSv for the duration of her pregnancy or the dose limit specified for pregnant workers under the *Nuclear Safety and Control Act* (Canada).
- When requested by a pregnant worker or by a worker intending to conceive a child, the employer must make counselling available with respect to the reproductive hazards associated with exposure to ionizing radiation.
F. Travelling with Your Radiation Badge

In general, radiation badges should not leave the work site (i.e. SFU campus). However, in some cases, as a result of research demands, it may be necessary to travel by air with your badge. If this is the case, it is recommended that you hand carry your badge through airport security. Leaving your badge in your checked or carry-on luggage will likely result in an exposure from the X-rays or CAT scanners used for security purposes and interfere with the measure of your occupational exposure to radiation. EH&S can provide you with a letter of explanation should you need to justify this practice.

Additionally, EH&S will provide a control badge, which should not to be used for occupational purposes during the trip
XIV. INTERNAL REVIEW OF RADIATION SAFETY PROGRAM

Compliance with internal and external regulations is confirmed through annual inspections carried out by Radiation Safety staff. Sample inspection sheets for a laboratory using Open Sources (i.e. unsealed nuclear substances) and Sealed Sources can be found in Appendix V – Internal Inspection.

If items of non-compliance are observed, confirmation should be obtained that the items are corrected, either immediately at the time of inspection or for more complicated items of non-compliance, through a re-inspection.

Compliance with internal and external regulations is governed by SFU Policy R20.04 and more specifically by the Measures to Promote the Safe Use of Radiological materials. (See Section II MEASURES TO PROMOTE THE SAFE USE OF RADIOLOGICAL MATERIALS, pages 7-8)
XV. DECOMMISSIONING OF RADIOISOTOPE LABORATORIES

In order to decommission a designated radioactive laboratory or enclosure such as refrigerator or freezer, the following conditions must be satisfied:

- Comprehensive swipe tests of the area or the enclosure must show that non-fixed contamination meets the licence criteria shown in Table IX-3 and Table IX-4 of Section IX Contamination Checks.
- If fixed contamination exists, the release of the room or the enclosure must be approved by the CNSC or a person authorized by the CNSC.
- All nuclear substances and radioactive devices must be transferred to another approved area.
- All radioactive signs must be removed or defaced.
- A copy of the swipe tests must be forwarded to the Program Manager, Ionizing Radiation Safety. Upon approval from the Program Manager, Ionizing Radiation Safety, the room may be returned to general use.
- The copy of the swipe tests must be kept on file by Radiation Safety staff.
XVI. INCIDENTS, ACCIDENTS AND EMERGENCIES

A. Spill Kit

An authorized laboratory should have 24-hour access to a radioactive spill clean-up kit, either in the laboratory itself or in a laboratory within close proximity. This kit should include:

- a plastic bucket,
- swipes,
- garbage bags,
- plastic bags to be used shoe covers, ‘footsies’
- electrical tape for securing plastic bags as shoe covers,
- scintillation vials,
- flagging tape,
- paper towels,
- “Caution - Radioactive Materials” warning signs,
- Count-Off™ spray or other suitable decontaminant,
- diapers, spill pads
- marking pens
- protective gloves (nitrile, latex, vinyl, or neoprene)

All these items are available in SFU Science Stores.
B. Spill Management

IN CASE OF RADIOACTIVE MATERIAL SPILL

Call for Help
Contain the Spill
Secure the Area to Prevent Further Access

Call for Help
- If you are in immediate physical danger, leave the area; call Campus Security, local 2-4500
- If there are injuries, call Campus Security, local 2-4500
- Call co-worker, lab supervisor, and Radiation Safety staff for assistance. You MUST contact Radiation Safety staff, even if the spill occurs after hours:

Radiation Safety Contact Information:

Director, Laboratory and Research Safety local: 2 7265 cell: (604) 375-3310
Radiation Safety Officer local: 2 3633 cell: (604) 512-7238
Radiation Safety Technician local: 2-3506 cell: (604) 551-5692

Contain the Spill
- Check for contamination on yourself and or your co-worker.
- Remove contaminated clothing and place in a plastic bag. Paper suits are available from the Radiation Safety Technician in the Hot Lab.
- Wear a lab coat and two pairs of gloves for decontamination. Change gloves frequently.
- Wear shoe covers or plastic bags bound with electrical tape or elastic bands around the ankles to prevent spreading the contamination.
- For dry contamination on yourself, use masking or adhesive tape to remove it.
- For wet contamination on yourself, use mild soap and rinse with lukewarm water taking care not to spread the contamination. If this fails, consult the Program Manager, Ionizing Radiation Safety to find a suitable solvent. See also Section C Skin Contamination.
- Don't rub skin harshly as this may cause skin damage.
- Once you are convinced that you have removed any contamination from yourself, begin to assess the area
- Determine the extent of the area contamination with a monitor or wipe tests.
- Delineate the contaminated area with a grease pencil or flagging tape.
- Remove any broken glass with tongs or forceps.
• Soak up liquid spills with “diapers” or absorbent pads. For dry spills, soak paper towels in water or decontaminant and place on top of the dry material. Scoop up using a dust pan and remember to decontaminate the dust pan.
• Use Count-Off™ spray for decontamination of surfaces, working from the outside to the centre of the spill area.
• Test for residual activity using the survey meter or swipe tests.
• Repeat process of decontamination until the area is clean or until swipe tests yield consistent results indicating no further decontamination is possible.
• Place decontamination materials in a plastic bag. Seal and label the bag with a waste tag and note the tag number in the inventory sheet.
• Monitor the persons involved in the decontamination as well as yourself for personal contamination. Remember to check the soles of shoes.

Secure the Area

• Secure the area against further access with flagging tape.
• Post Radiation Warning Signs.
• Do not resume work until the area is assessed by Radiation Safety Staff.

C. Skin Contamination

• The CNSC has a specific protocol for addressing skin contamination events.
• All skin contamination events must be documented, recorded and investigated.
• It may be necessary to report the incident to the CNSC, depending on the dose to the skin.
• There are three steps in the skin contamination response:
  • Phase I – Measuring the contamination and decontaminating the skin
  • Phase 2 – Calculating the Skin Dose
  • Reporting to the CNSC, if necessary
• See the flow charts from the CNSC for Phase 1 and Phase 2 on subsequent pages.
PHASE 1 - MEASURING THE CONTAMINATION

Measure & record NET count rate (counts per minute - CPM) and time

Is NET CPM above zero?

N

No need for immediate decontamination

Y

Decontaminate

Measure and record NET CPM and time

Repeat decontamination

Y

Measure & record NET CPM & time. Is the CPM still decreasing?

N

Is the individual a NEW?

Y

Were the initial NET CPM and final NET CPM below 10,000 and 500 respectively and recorded within 1 hour of each other?

N

No requirement to explicitly calculate skin dose. Worst case is below 50 mSv. Go directly to Phase 3.

Y

Skin dose must be calculated. Go to Phase 2.
**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 (cm²) 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 cm².

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

**DCF:** Dose conversion factor (μSv/h per Bq/cm²) 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 subsequent measurement

**PHASE 2 - CALCULATING THE SKIN DOSE**

Determine Bq/cm² for each measurement:

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

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

\[
D = \frac{Bq}{cm^2} \times DCF \times 1.443 \times T1/2 \times \left[1 - e^{-0.693T/T1/2}\right]
\]

**Was the final NET CPM zero?**

**N**

**Y**

**PHASE 3 - REPORTING TO THE CNSC**

Was the individual a NEW?

**N**

Was the calculated dose above 50 mSv?

**Y**

**Report immediately to the CNSC.**

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

Was the calculated dose above 5 mSv?

**N**

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 occurrences.
Appendix 1 – 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 cm², skin decontamination unsuccessful beyond the 500 CPM, and a 27-day exposure). Consequently, the default screening level(s) for which ascertainment 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 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 activity. 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. Those 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 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 ($\mu$Sv/h per Bq/cm$^2$):

<table>
<thead>
<tr>
<th></th>
<th>C-14</th>
<th>F-18</th>
<th>P-32</th>
<th>Ga-67</th>
<th>Y-90</th>
<th>Te-99m</th>
<th>In-111</th>
<th>I-123</th>
<th>I-125</th>
<th>I-131</th>
<th>TI-201</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.32</td>
<td>1.9</td>
<td>1.9</td>
<td>0.35</td>
<td>2.0</td>
<td>0.25</td>
<td>0.38</td>
<td>0.38</td>
<td>0.021</td>
<td>1.6</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Reference: IAEA-TECDOC-1162

Excerpted from DNSR article – CNSC Expectations for Licensee Response During Skin Contamination Events.
May 2016, Canadian Nuclear Safety Commission, p1-5.
D. Reporting Requirements for Spills and Contamination Events

REPORTING TO RADIATION SAFETY STAFF

Report all spills, incidents, contamination events or suspected contamination events and near misses involving nuclear substances or radiation emitting devices to the Radiation Safety contacts using the twenty-four hour contact information on page 53. An online incident report should be completed at: http://www.sfu.ca/srs/report-incident-online.html

REPORTING TO THE CNSC

The following occurrences require immediate reporting to the CNSC by Radiation Safety staff:

- any spills or incidents that involve more than 100 Equivalent Quantities of radioactive material or the release of volatile material
- an extremity skin dose above 50 mSv for a NEW or an extremity skin dose above 5 mSv for a non-NEW
- unauthorized release of radioactive material into the environment
- attempt or actual breach of security
- act of sabotage
- failure or degradation of a system which is likely to contribute adversely to health or safety of people, a threat to the environment, or maintenance of security.
XVII. SECURITY of RADIOLOGICAL MATERIALS

To guard against thefts and/or losses of radiological materials, all radioactive sources must be secured from unauthorized access. As a rule, rooms where radioactive materials are stored or used must be kept locked at all times unless an authorized user is present in the room. Additionally, when radionuclides are in use, users are required to ensure that the source vial or sealed source is secured during the user’s absence.

Sealed sources
In the case of sealed sources or equipment containing a radioactive source, the room shall be kept locked when unattended by an approved radioisotope user.

Open Sources
Open sources shall be stored in a locked refrigerator, freezer or other suitable container, secured by a padlock. Padlocks are available from the Radiation Safety Technician. Should the storage container require modification to accommodate a padlock, arrangements can be made through Facilities Services via a work order for such modification. Note that in the case of the compact “bar” refrigerators, the refrigerator must be bolted to the floor to prevent removal. Facilities Services can also complete this work.

Non-Approved Users
Non-approved users may not be given access to radioactive sources. More generally, unfamiliar individuals loitering around research laboratories should be challenged as to their identity or their presence reported to Campus Security.

Thefts or losses of Radionuclides
The Program Manager, Ionizing Radiation Safety must report thefts or losses of radionuclides immediately to the CNSC. Consequently, if theft or loss is suspected, or if a pattern of loss of isotope is observed, contact Radiation Safety staff immediately. See also Section XVI, C. Reporting Requirements.
XVIII. TRANSPORTATION OF RADIOACTIVE MATERIALS

The packaging and transportation of radioactive materials is regulated within Canada by the Transport Canada Dangerous Goods Regulations and the Packaging and Transport of Nuclear Substances Regulations. Anyone packaging or transporting radioactive substances must hold a valid Transport of Dangerous Goods Certificate for Class 7 Radioactive Materials by road and air. Shipments of radioactive materials to or from SFU must be arranged through Radiation Safety staff.
APPENDIX I. Conversion Units.

Table A1-1. Conversion factors between radiation units.

<table>
<thead>
<tr>
<th>Unit Measured</th>
<th>To Convert From</th>
<th>To</th>
<th>Multiply By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity of Source</td>
<td>Curies (Ci)</td>
<td>Becquerels (Bq)</td>
<td>3.7 x 10^{10}</td>
</tr>
<tr>
<td></td>
<td>Becquerels (Bq)</td>
<td>Curies (Ci)</td>
<td>2.7 x 10^{-11}</td>
</tr>
<tr>
<td>Energy of Source</td>
<td>Joules (J)</td>
<td>Electron Volts (eV)</td>
<td>6.25 x 10^{18}</td>
</tr>
<tr>
<td></td>
<td>Electron volt (eV)</td>
<td>Joules (J)</td>
<td>1.6 x 10^{-19}</td>
</tr>
<tr>
<td>Absorbed Dose</td>
<td>Rad</td>
<td>Gray (Gy)</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Gray (Gy)</td>
<td>Rad</td>
<td>100</td>
</tr>
<tr>
<td>Proportionality</td>
<td>Radiation</td>
<td>Biological</td>
<td>1</td>
</tr>
<tr>
<td>Constant</td>
<td>Equivalent (RBE)</td>
<td>Quality Factor^1</td>
<td></td>
</tr>
<tr>
<td>Dose Equivalent^2</td>
<td>Rem</td>
<td>Sievert (Sv)</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Sievert (Sv)</td>
<td>Rem</td>
<td>100</td>
</tr>
</tbody>
</table>

1. See Table A1-2 for Quality Factor values.
2. Dose equivalent = Absorbed dose x Quality Factor

Table A1-2. Quality Factors for Ionizing Radiation

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Q-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-rays</td>
<td>1</td>
</tr>
<tr>
<td>Gamma Rays</td>
<td>1</td>
</tr>
<tr>
<td>Betas</td>
<td>1</td>
</tr>
<tr>
<td>Alphas</td>
<td>20</td>
</tr>
<tr>
<td>Neutrons</td>
<td>10</td>
</tr>
</tbody>
</table>
Table A1-3. Prefixes for Units.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Name</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>f</td>
<td>Femto</td>
<td>$1 \times 10^{-15}$</td>
</tr>
<tr>
<td>p</td>
<td>Pico</td>
<td>$1 \times 10^{-12}$</td>
</tr>
<tr>
<td>n</td>
<td>Nano</td>
<td>$1 \times 10^{-9}$</td>
</tr>
<tr>
<td>µ</td>
<td>Micro</td>
<td>$1 \times 10^{-6}$</td>
</tr>
<tr>
<td>m</td>
<td>Milli</td>
<td>$1 \times 10^{-3}$</td>
</tr>
<tr>
<td>k</td>
<td>Kilo</td>
<td>$1 \times 10^{3}$</td>
</tr>
<tr>
<td>M</td>
<td>Mega</td>
<td>$1 \times 10^{6}$</td>
</tr>
<tr>
<td>G</td>
<td>Giga</td>
<td>$1 \times 10^{9}$</td>
</tr>
<tr>
<td>T</td>
<td>Tera</td>
<td>$1 \times 10^{12}$</td>
</tr>
</tbody>
</table>
APPENDIX II - Permit Application Form.

Simon Fraser University
Radiation Safety
Application for Internal Radioisotope Permit

1. Please complete the following personal information:

Name of prospective permit holder: _______________________________________________________

Department: ________________________________  Office Telephone: _________________________

Home Telephone (in case of emergency): ______________  Lab  Telephone: _______________

e-mail address: __________________________________________

2. Names(s) of individual(s), other than applicant, who will be handling radioactive materials:

___________________________________________________________________________________

___________________________________________________________________________________

___________________________________________________________________________________

3. University location(s) where radioactive materials will be manipulated and stored (list room num-

bers):

___________________________________________________________________________________

4. Radioisotopes required:

<table>
<thead>
<tr>
<th>Open Sources</th>
<th>Sealed Sources</th>
<th>Maximum activity to be stored in the licensed location(s)</th>
<th>Maximum activity to be used during an experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

continued
Application for Internal Radioisotope Permit (continued)

5. List below the type of counting instruments intended for use for contamination monitoring (e.g. liquid scintillation counter, Geiger-Mueller counter):

_____________________________________

_____________________________________

_____________________________________

_____________________________________

6. Brief statement of intended use of radionuclides

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

7. The applicant warrants the statements contained herein and agrees that the radioisotopes supplied against this application shall only be used for purposes and in the manner authorized by the SFU Radiation Safety Committee and in accordance with SFU Policy R 20.04 Radiological Safety.

______________________________________________________________
Signature of Applicant

__________________________
Date

file: forms/permapp.doc
APPENDIX III - Leak Testing Protocol for Sealed Sources.

Radiation Safety staff undertake both leak test sampling and measuring for sealed sources. As a result, the measuring and sampling certificates are combined. Leak testing is provided solely as an “in house” service for Simon Fraser University. The leak test sampling and measuring is carried out by the Radiation Safety Technician, who is familiar with radiation safety principles, the operation of the Liquid Scintillation Counter and the requirements of the Canadian Nuclear Safety Commission for leak test sampling and measuring. Results are monitored by the Radiation Protection Officer. Sampling and Measuring Procedures for the SFU Leak Testing Program are detailed below.

Sealed sources of activity greater than 50 MBq are leak tested. For sources which are continually in storage, the frequency of sampling and measuring is every 24 months. For sources in a device, the frequency of sampling and measuring is every 12 months. All other sources must be sampled and measured every 6 months. If the leakage from any source exceeds 200 Bq or 50 Bq of radon in 24 hours, the source must immediately be taken out of service and the CNSC notified within 24 hours. Leak test results are maintained by Radiation Safety staff. The leak sampling and measuring form is shown in Fig. A3-1.

LEAK TEST SAMPLING

1) SAMPLING METHOD:
The source or source housing is wiped with a commercially available, pre-packaged, alcohol moistened towelette (approximately 7 x 3 cm²).

2) TYPES OF SOURCES.
There are three types of sealed sources requiring wipe test procedures:

- the inner column (removed from nuclear gauge by cert. consultant, UniVert Tech Inc.) in which the source moves is wiped.
- electron capture detectors in 2 gas chromatographs (Chemsitry, REM): as described in the manufacturer’s manual.
- In cases where the manual is not available, the detector port is wiped.

3) HANDLING OF SWIPES.
Following the wipe test, the wipes are placed in empty, labeled, 10 ml scintillation vials. The labeled vials containing the wipes are taken to SSC-B7249, the Hot Lab, for counting on one of the Liquid Scintillation Counters.

LEAK TEST MEASURING.

1) PREPARATION OF WIPES FOR ACTIVITY MEASUREMENT.
Five ml of scintillation cocktail is added to each scintillation vial and the wipes are counted for two minutes on the Liquid Scintillation Counter. A blank sample, containing only scintillation fluid, is also counted for two minutes to establish background. All samples are counted on a wide open window.
2) ACTIVITY MEASUREMENT.
Wipes are counted on one Liquid Scintillation Counters (LSC) located in SSC-B7249 and maintained by the Radiation Safety Technician. However, if required, there are also three other LSC research instruments available from various departments at SFU. Manuals for the LSC are available in SSC-B7249, Hot Lab and from the owners of the “other” LSC.

EQUIPMENT CALIBRATION.

The LSCs are calibrated monthly as per the instructions in the manufacturer’s manual with an unquenched, H-3 standard provided by the manufacturer. The efficiency is checked twice monthly using unquenched, sealed standards of H-3, C-14, and a blank, supplied by the LSC manufacturer. Additionally, Radiation Safety at SFU participates in the annual C-14 and H-3 intercomparison study carried out by the Radiation Protection Bureau to verify reproducibility and accuracy. Previous intercomparison results attest that we can reliably detect 50 Bq of H-3 and 20 Bq of C-14. Detection efficiencies for the various isotopes for which leak tests are performed are conservatively taken as one-half the manufacturer’s values for the isotopes of interest. The method for calculating the expected MDA (Minimum Detectable Amount) is shown below.

CALCULATION OF MINIMUM DETECTABLE AMOUNT (MDA).
The MDA may be estimated using first Eq. (A6-8) from Appendix VI:

\[
cpm_{\text{Net}}^{(\text{minimum})} = \frac{1}{2 \times \Delta t \times \left(\frac{\%err}{100}\right)^2} \left( 1 + \sqrt{1 + 8 \times \Delta t \times cpm_{\text{Bkg}} \times \left(\frac{\%err}{100}\right)^2} \right)
\]

where \(\%err\) is the desired percent error on the result, \(\Delta t\) the duration of counting in minutes and \(cpm_{\text{Bkg}}\) the background count rate. Then the MDA in Bq can be obtained knowing the efficiency of the detector:

\[
\text{MDA (in Bq) } = \frac{cpm_{\text{minimum}}}{60 \times \text{efficiency}}
\]

Sample calculation:
Let \(\%err = 5\%, cpm_{\text{Bkg}} = 30\) cpm, efficiency = 50\% and \(\Delta t = 2\) min.

\[
cpm_{\text{minimum}} = \frac{1 + (1 + 8\times10^{-4} \times 5^2 \times 30 \times 2)^{1/2}}{(2\times10^{-4} \times 5^2 \times 2)} = 248\text{ cpm}
\]

Finally, MDA = 248/(60 x 0.5) = 8.3 ± 0.4 Bq
Leak Test Sampler and Measurer: Radiation Safety, Simon Fraser University, 8888 University Drive, Burnaby, B.C. V5A 1S6

Licensee: Simon Fraser University, Burnaby, B.C. CNSC licence #07342-2-12.13

Contact:
Kate Scheel, Radiation Safety  Tel: (778) 782-3633  email: scheel@sfu.ca

Sealed Source I.D.:

<table>
<thead>
<tr>
<th>Isotope:</th>
<th>SFU I.D. #:</th>
<th>Permit Holder:</th>
<th>Permit Number:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Device Model #:</th>
<th>Device Serial #:</th>
<th>Source Model #:</th>
<th>Source Serial #:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Isotope Energies:</th>
<th>Half-life:</th>
<th>Location (Room No.):</th>
<th>LSC Efficiency:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sampling Measuring Date</th>
<th>LSC Calibration Date</th>
<th>LSC Verification Check Date</th>
<th>Background</th>
<th>Measurement Value</th>
<th>Calculated Activity*</th>
<th>Results &lt; or &gt; 200 Bq</th>
<th>Action (who notified, how, date of notification)</th>
<th>Signature of Sampler/Measurer</th>
</tr>
</thead>
</table>

Sampling Method:

Measuring Method: Swipes are counted on a Liquid Scintillation Counter with maximum window for 2 minutes.

*Calculation of Activity:

\[
\text{Measurement value (cpm) - Background (cpm)} = \text{Results (Bq)} \\
60 \text{ Bq/dpm (LSC Efficiency)}
\]
APPENDIX IV – Thyroid Screening for Radioiodine

Individuals exposed to radioiodine under the criteria of Table XIV-2 must complete a thyroid screening using the following protocol:

**THYROID SCREENING**

1) **QUALITY CONTROL VERIFICATION**
   - On the day of the screening, measure and record the ambient background count rate, accumulating at least 400 counts.
   - Measure and record the net count rate of a standard
   - Verify that the ambient background and net standard count rates are within acceptable values

2) **SCREENING MEASUREMENT**
   - Measure and record the exposed individual’s background count rate by taking the measurement on the individual’s lower thigh or with a neck phantom
   - Measure and record the individual’s gross count rate from the thyroid. The detector should be positioned 7 cm from the neck using the guide and positioned in the triangle formed between the Adam’s apple and clavicle.
   - Calculate the individual’s net count rate from the thyroid (gross thyroid measurement minus background thigh measurement)
   - Record the net count rate in the thyroid screening log (see sample log)
   - Compare net counts to those in the following chart to determine appropriate action
Validation of Screening Results

- **Measurement results ≥ 1 kBq?**
  - **yes**
    - Repeat and verify measurement
  - **no**
    - **Screening complete**

- **yes**
  - **Clothes and skin contaminated?**
    - **no**
      - **Screening complete**
    - **yes**
      - Decontaminate skin and/or remove clothing; repeat measurement

- **Measurement results ≥ 1 kBq?**
  - **no**
    - **Screening complete**
  - **yes**
    - **Measurement results >10 kBq?**
      - **no**
        - Investigate to determine and correct cause of results; report findings; correct deficiencies; record event in annual compliance report
      - **yes**
        - Investigate and correct cause; record event in annual compliance report

- **yes**
  - **Measurement results >10 kBq?**
    - **no**
      - Validate results; inform CNSC immediately; have a bioassay done by CNSC licensed operator; determine committed effective dose; perform internal investigation to determine and correct cause, including area and contamination monitoring; record event in annual compliance report
    - **yes**
      - Validate results; inform CNSC immediately; have a bioassay done by CNSC licensed operator; determine committed effective dose; perform internal investigation to determine and correct cause, including area and contamination monitoring; record event in annual compliance report
### SAMPLE THYROID SCREENING LOG

<table>
<thead>
<tr>
<th>Measurement date Yr-month-day</th>
<th>Last date of use Yr-month-day</th>
<th>Background counts</th>
<th>Count time (seconds)</th>
<th>Background cps</th>
<th>Thyroid counts</th>
<th>Count time (seconds)</th>
<th>Thyroid cps</th>
<th>Net cps (thyroid-background)</th>
<th>Technician (initials)</th>
<th>Action taken</th>
</tr>
</thead>
</table>
QUALITY CONTROL Chart

<table>
<thead>
<tr>
<th>Date</th>
<th>Background Count Rate</th>
<th>Standard Source Count Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Acceptable Background Rate

Acceptable Standard Count Rate

After approximately 20 days of counting, determine the standard deviations for the distributions as per RD-58 Thyroid Screening for Radioiodine
APPENDIX V - Internal Inspection

Verification of Compliance is accomplished through internal inspections. These are conducted at least annually. All inspections are done with the iAuditor program on the iPad. The content of the inspection checklists for sealed and open sources can be found on the following pages.

The laboratory is notified of the inspection results through email. In cases where compliance is compromised, the laboratory may be re-inspected to verify compliance.
Simon Fraser University
Radiation Safety Inspection Report

Open Source Lab

Permit# Permit Holder Room #

<table>
<thead>
<tr>
<th>SIGNAGE</th>
<th>Inspection</th>
<th>Re-inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is the current permit posted on the outside of the door?</td>
<td>yes no</td>
<td>yes no</td>
</tr>
<tr>
<td>2. Are all users listed on the permit?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Are the following signs posted:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Hazardous Materials Sign?</td>
<td>yes no</td>
<td></td>
</tr>
<tr>
<td>i. Emergency Contact #’s on the door?</td>
<td>yes no</td>
<td></td>
</tr>
<tr>
<td>ii. Yellow “DANGER Radiation” sign on Door?</td>
<td>yes no</td>
<td></td>
</tr>
<tr>
<td>iii. Lab Rules poster in work area?</td>
<td>yes no</td>
<td></td>
</tr>
<tr>
<td>iv. “In Use” signs in hot areas?</td>
<td>yes no</td>
<td></td>
</tr>
<tr>
<td>4. Are radioactive equipment/ glassware/ and samples used for radioactive work labeled as radioactive?</td>
<td>yes no</td>
<td></td>
</tr>
<tr>
<td>5. Is high level waste labeled as radioactive with isotope name?</td>
<td>yes no</td>
<td></td>
</tr>
<tr>
<td>6. No non-radioactive items labeled as radioactive?</td>
<td>yes no</td>
<td></td>
</tr>
</tbody>
</table>

| LAB PRACTICE                                               |            |               |
| 7. Are hot benches covered with bench paper?               | yes no     |               |
| 8. Are emergency supplies available?                      |            |               |
| location: _______________________________________________ | yes no     |               |
| 9. Is there a low level radioactive waste can?             | yes no     |               |
| 10. Is excess liquid and/or solid waste transferred to the Hot Lab (SSC-B7249)? | yes no     |               |
| 11. No coffee cups/food items in lab?                      | yes no     |               |
| 12. Are radioisotopes secured with a combination lock on the fridge/freezer or other storage area? (NOTE: bar fridges must be secured to the floor) | yes no     |               |
| 13. Are radioactive equipment/glassware decontaminated and decontamination verified with wipe tests before returning equipment/glassware to general use? | yes no     |               |
| 14. Is there a monitor or Geiger counter available?        | yes no     |               |
15. Is the monitor functioning? [ ] yes [ ] no

16. Is there a vinyl chair, wooden stool, or other suitably covered seat? [ ] yes [ ] no

17. Do users monitor their hands and clothes after radioactive work? [ ] yes [ ] no

**DOCUMENTATION**

18. Is there an inventory of isotopes in refrigerator/storage enclosures on the refrigerator/enclosure door? [ ] yes [ ] no

19. Are weekly wipe tests being done? [ ] yes [ ] no

20. Is current inventory of usage maintained? [ ] yes [ ] no

21. Is the waste path documented on the inventory sheet? [ ] yes [ ] no

22. Is the waste transferred to the Hot Lab (SSC-B7249) given an identifying label which is noted on the inventory sheet? [ ] yes [ ] no

**FOR HARD BETA AND GAMMA USERS**

23. Do users know where badge results are posted? [ ] yes [ ] no

24. If I-125 is in us, are bioassays done as required? [ ] yes [ ] no

__________________________________________________________

Other Comments/Swipe Test results:

____________________________________________________________________________________________

Inspection conducted in presence of: ____________________ Probable CNSC grade: ______

| Date of Inspection | Date of Re-Inspection |
Sealed Source/Source in a Device

<table>
<thead>
<tr>
<th>Permit#</th>
<th>Permit Holder</th>
<th>Room #</th>
<th>Inspection</th>
<th>Re-inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

**SIGNAGE**
1. Is the current permit posted on the door? [ ] [ ] [ ] [ ]
2. Are all users listed on the permit? [ ] [ ] [ ] [ ]
3. Are the following signs posted:
   - i. Name and telephone number for 24-hour Emergency Contact #’s on the door? [ ] [ ] [ ] [ ]
   - ii. Yellow “DANGER Radiation” Warning on Door? [ ] [ ] [ ] [ ]

**LAB PRACTICE**
5. No coffee cups/food items in lab? [ ] [ ] [ ] [ ]
6. Is access to radioisotopes restricted? [ ] [ ] [ ] [ ]
   (For sealed source, source must be stored in a locked container, secured to the floor or wall)
7. Is dose rate less than 2.5 μSv/hr? [ ] [ ] [ ] [ ]
8. Is there a monitor or Geiger counter available? [ ] [ ] [ ] [ ]

Location of nearest calibrated monitor

**DOCUMENTATION**
9. Is there an inventory of isotope(s) in storage enclosures on the enclosure door? [ ] [ ] [ ] [ ]

**FOR HARD BETA AND GAMMA USERS**
10. Do users know where badge results are posted? [ ] [ ] [ ] [ ]

**FOR GAS CHROMATOGRAPHS ONLY**
11. Is the G.C. labelled with source type and activity? [ ] [ ] [ ] [ ]
12. Is the G.C. labelled with a radioactive sign? [ ] [ ] [ ] [ ]
13. If the source is H-3, is it vented through the fume hood? [ ] [ ] [ ] [ ]
14. Is the source or device labeled with name and telephone number for 24-hour emergency contact? [ ] [ ] [ ] [ ]
### FOR NUCLEAR GAUGE

15. Is the gauge affixed with a steel tag bearing the radionuclide, activity, and the radioactive trefoil symbol?  
   | Inspection | Re-inspection |
   | yes | no | yes | no |

16. Is the case affixed with a steel tag bearing the radionuclide, activity, and the radioactive trefoil symbol?  
   | Inspection | Re-inspection |
   | yes | no | yes | no |

17. Is the following documentation present?  
   - i) CNSC Emergency Procedures poster INFO 0483?  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - ii) a fire and water resistant radioactive placard?  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - iii) a dangerous goods shipping manifest?  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - iv) an exemption permit for transport in British Columbia?  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - v) a Type A package certificate?  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - vi) a Special Form Certificate?  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - vii) a leak test certificate  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - viii) log book in which to record use  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - ix) radioactive signs in case of emergency  
     | Inspection | Re-inspection |
     | yes | no | yes | no |
   - x) a copy of the University Radioisotope License?  
     | Inspection | Re-inspection |
     | yes | no | yes | no |

### Other Comments:

Inspection conducted in presence of: _________________  
Probable CNSC grade: ___________

<table>
<thead>
<tr>
<th>Date of Inspection</th>
<th>Date of Re-Inspection</th>
</tr>
</thead>
</table>
APPENDIX VI - Counting Statistics
J.-C. Brodovitch

I. ESSENTIAL EQUATIONS

All of what follows can be derived from two equations:

1) For $M$ radioactive decay events (i.e. $M$ counts), the standard deviation is $\sqrt{M}$, in other words, the observed number of counts is:

$$M \pm \sqrt{M}$$

(1)

2) For a sum (or a difference), the absolute errors add up in quadrature, i.e.

$$\text{Err}^2(a \pm b) = \text{Err}^2(a) + \text{Err}^2(b)$$

(2)

Applying these two principles to a sample for which one measures $T$ counts (Total counts) and $B$ counts for the background in the same time interval $\Delta t$, $N$ the net counts due to the sample is:

$$N = T - B$$

(3)

Then the standard deviation on $N$:

$$\text{Err}^2 N = \text{Err}^2 T + \text{Err}^2 B = T + B$$

(4)

or

$$\text{Err}(N) = \sqrt{T + B}$$

(5)

or expressed as relative error (in three different ways)

$$%\text{err}(N) = \frac{\text{Err}(N)}{N} \times 100 = \frac{\sqrt{T + B}}{T - B} \times 100 = \frac{\sqrt{N + 2B}}{N} \times 100 = \frac{(S + 1)}{B(S - 1)^2} \times 100$$

(6a)

where $S = \frac{T}{B}$

(6b)

Note that Eqs. (5) and (6) give the value of one standard deviation, or 67% confidence level interval. In many disciplines, the error reported is the 95% confidence level, which corresponds to two standard deviations. For this matter, it is this last quantity which is reported as % error in the output of Liquid Scintillation Counters.

The quantity $S$ in Eqs. (6a) and (b) is related to the so-called signal-to-noise ratio; it describes by how much the sample count “sticks out” of the noise (the background). If $S = 1$ (i.e., $T = B$), there is no signal. If $S >> 1$ ($T >> B$), there is plenty of signal and life is easy. A problem arises when $S > 1$ while $S = 1$. In this case, given that there are experimental uncertainties attached to the values of $T$, $B$ and consequently of $S$, one may be faced with the question: is really $S > 1$ and if so, by how much? In other words, does my sample contain significant activity?
II. MEANING OF THE TWO STANDARD DEVIATIONS (OR 95% CONFIDENCE LEVEL)

Reporting an experimental result with its 95% conf. level assumes that the particular measurement obeys a normal distribution which in turn means that if the experiment were to be repeated, there is a 95% chance that the new result would agree with the previous result within the quoted interval (or to state it as pollsters like to do it: the result is considered accurate within the quoted interval 19 times out of 20).

EXAMPLE OF RADIOACTIVE COUNTING.
If one collects 100 counts in a given time interval, the 95% conf. level is 
\(2 \times 100^{1/2} = 20\).

If one were to recount for the same duration the same sample over and over, 95% of the measurements (19 out of 20) would fall in the interval 80 – 120 counts (after appropriate correction for decay if the half-life is “short”).

III. FOR HOW LONG SHOULD I COUNT?

For how long should I count to get the net cpm (net = gross – blank) of my sample within a predetermined percent error?

This question arises mostly for low activity samples. It is totally related to the question: is this cpm significantly higher than my background, or is there really some activity in this particular sample? High activity samples (> 1000 cpm), since they stand out of the background, do not present a problem in general.

From Eq. (6b), \(S = \frac{T}{B} = \frac{cpm_{Gross}}{cpm_{Bkg}}\). Let \(\%err\) be the desired percent standard deviation.

Then, the minimum counting time \(\Delta t_{min}\) to get net cpm of sample within \(\%err\) is obtained by rearranging Eq. (6a):

\[
\Delta t_{min} = \frac{1}{cpm_{Bkg}} \cdot \frac{S + 1}{\left(\frac{\%err}{100}\right)^2 (S - 1)^2}
\]  
(7)

EXAMPLE:
After a quick count (say, 2 min per sample), the following is obtained: \(Bkg = 21\) cpm and \(Gross = 34\) cpm for the sample. Under these conditions, the percent error on these two pieces of data is respectively 15% and 12% (one standard deviation). This means that \(Bkg = 21 \pm 3\) cpm and \(Gross = 34 \pm 4\) cpm. The net cpm is then:
\(Net = Gross - Bkg = 34 - 21 = 13\) cpm
and the error on \(Net\), using elementary error propagation calculation of Eq. 5,
\(Err_{Net} = \sqrt{Err_{Gross}^2 + Err_{Bkg}^2} = \sqrt{3^2 + 4^2} = 5\)

i.e., \(Net = 13 \pm 5\) cpm (±38% standard deviation) or \(Net = 13 \pm 10\) (with 95% conf. level!), meaning that I can be 95% confident that \(Net\) is anywhere between 4 and 22 cpm.
If I want to know the net cpm with a standard deviation of 10% (ie, cpm ± 20% with 95% conf. level), using Eq. (7) above, the minimum counting time is calculated as ≈33 min. One can verify that for such a length of time, the results would be (using the same cpm values, and the 95% conf. interval):

\[ Bkg = 21 \pm 1.6 \text{ cpm (8\% error)} \] and \[ Gross = 34 \pm 2.1 \text{ cpm (6\% error)} \]

Then again:

\[ Net = Gross - Bkg = 34 - 21 = 13 \text{ cpm} \]

\[ Error_{Net} = \sqrt{Error_{Gross}^2 + Error_{Bkg}^2} = \sqrt{2.1^2 + 1.6^2} = 2.6 \]

i.e., \[ Net = 13.0 \pm 2.6 \text{ cpm (20\%)} \], Now I can say with a 95% confidence level that my \[ Net \] is between 10.4 and 15.6 cpm.

### IV. MINIMUM DETECTABLE ACTIVITY

For a given counting time duration, how low a net cpm can I measure with a given percent error?

For example. I routinely count my samples for two minutes; what is the lowest net cpm I can trust accepting a 20% standard deviation on this value.

This is called sometimes the minimum detectable activity (MDA), for a given counting duration and a given expected error.

The formula to use is a rearrangement of equation (7) after solving for net \( cpm_{net}^{\text{minimum}} \):

\[
 cpm_{Net}^{\text{minimum}} \equiv MDA = \frac{1}{2 \times \Delta t \times \left( \frac{\%err}{100} \right)^2} \left( 1 + \sqrt{1 + 8 \times \Delta t \times cpm_{Bkg} \times \left( \frac{\%err}{100} \right)^2} \right)
\]  

(8)

where \( \Delta t \) is the counting time duration in minutes, and \( \%err \) the desired percent standard deviation.

**EXAMPLE:**

I count my swipe test samples for 1 min. To decide whether some surface contamination is present I must be able to detect reliably (± 20\%) 100 cpm. Is a 1 min count sufficient?

One must determine the Bkg cpm, then use formula (8) above with \( \Delta t = 1 \) min and \( \%err = 20 \). Let set \( Bkg = 20 \text{ cpm (typical value)} \). One gets \( MDA = 130 \text{ cpm} \), a bit on the tight side. 1.5 min counting duration would be ideal.
APPENDIX VII - Laboratory Design Requirements

The Canadian Nuclear Safety Commission provides recommendations for the design of Nuclear Substance Laboratories in document *GD-52 Design Guide for Nuclear Substance Laboratories and Nuclear Medicine Rooms*. The guide describes finishing of floor and wall surfaces, plumbing, ventilation, and other design features. The full document is available online from the CNSC website. In general:

- all surfaces (floors, walls, countertops, interior of fume hoods) should be smooth, and covered with an impervious, washable finish; any joints in the surface material must be sealed
- a separate hand washing sink and a wash-up/disposal sink will be provided
- An emergency eye-wash station will be provided in the room or in close proximity to the room.
- If volatile materials or materials that may generate aerosols or gases are being used, the room will be at negative pressure with the surrounding area (unless the room will be used as a clean or sterile room). Air flow will always be from the area of low radiation.
- General laboratories will have a minimum of 6 air changes per hour.
- Air vented through the fume hood will be vented without recirculation.
- Fume hoods will be located away from areas of air currents or turbulence (high traffic areas, doors, operable windows, air supply diffusers).
- Fume hoods will not be located adjacent to a single means of access to an exit, due to possible volatility of the fume hood contents.
- The face velocity of the fume hood will be at a minimum of 0.5 m/s.
- Each fume hood will have a continuous monitoring device for proper functioning of the hood. An alarm, either visual or audible, will be present to indicate reduced air flow.
- Provisions will be in place to ensure the fume hood remains functional if a routine automatic after-hours shutdown system is in place.
- Fume hoods will not contain filters. (If filtration will be required because nuclear substances will be released regularly through the fume hood exhaust or because biohazards are present, then detailed information about the filtration including filter monitoring and exchanges will be supplied.)
- Food and drink preparation, use, and storage areas will not be present in the room unless required as part of a nuclear medicine procedure.
- Office and study space will not be located near radioactive work areas.
- Rooms will have sufficient counter and floor space to allow people to work safely. (In general, allow at least 3 square meters of free floor space for each worker.)
APPENDIX VIII - Notification of Nuclear Energy Worker Status

A Nuclear Energy Worker (NEW) is a person who might receive an occupational radiation dose greater than 1 mSv/year. The NEW classification is made by Radiation Safety staff. According to the Radiation Protection Regulations, every licensee shall inform each nuclear energy worker, in writing,

1. a) that he or she is a nuclear energy worker;
   b) of the risks associated with radiation to which the worker may be exposed in the course of his or her work, including for women, the risks associated with the exposure of embryos and fetuses to radiation;
   c) of the applicable effective dose limits and equivalent dose limits
   d) of the worker's radiation dose levels.

2. The licensee shall also inform each female nuclear energy worker, in writing of the rights and obligations of a pregnant NEW and the effective dose limits.

3. Every licensee shall obtain from each nuclear who is informed of the above written acknowledgment that the worker has received the information.

I have received information regarding the risks associated with the radiation to which I am exposed, of the dose limits and of my radiation dose level.

_________________________________   ____________________________________
Signature                        Date
APPENDIX IX - Liquid Scintillation Counting

A. INTRODUCTION

The process by which radioactive decay energy is converted to visible light and measured in an organic liquid environment is called LIQUID SCINTILLATION COUNTING (LSC). In Liquid Scintillation Counting, the amount of light produced is proportional to the amount of radiation present in the sample and the energy of the light produced is proportional to the energy of the radiation that is present in the sample. This makes LSC a very convenient tool to measure radioactivity.

B. THE SCINTILLATION PROCESS

The radioactive sample to be measured is combined with a scintillation cocktail. Scintillation cocktail is a mixture of an organic solvents; an emulsifier which ensures proper mixing of aqueous samples in the organic solvents; and a fluor, a substance which has the capability of fluorescing when excited by the radioactive substance. The light that is produced from the excitation of the cocktail by the radioactivity is directed to the photomultiplier tubes, which then convert the light into a measurable electrical pulse (see Figure 1). The amplitude of the pulse is proportional to the amount of light that has reached the photomultiplier tubes. Therefore, the pulse height at the output of the tubes is proportional to the energy of the radioactive sample. In order to discriminate between true radioactive decay events and the electrical background noise of the photomultiplier tubes, LS counters have a coincidence gate which allows measurement only of those events which occur simultaneously at both photomultiplier tubes.

The pulses from the photomultiplier tubes are analyzed, converted to digital form, and stored in the appropriate channel of a multichannel analyzer, corresponding to the radiation energy (Figure 2). This ability to sort the pulses detected according to their amplitude allows discrimination between emissions of different energies. For example, three commonly used isotopes $^3$H, $^{14}$C, and $^{32}$P have beta energies of 18.3, 156 and 1,710 keV respectively. By setting windows judiciously, it is possible to specify which energy range is to be measured.
Figure I  A block diagram of a scintillation counter

Figure II Pulse Height Spectra of Three Radioisotopes from a Liquid Scintillation Counter
C. QUENCH

Anything added to a counting vial (colour, solvents, filters, swabs) can reduce the efficiency of the scintillation process. This reduction in counting efficiency is called quench, for short. The three major forms of quench are:

1. **Chemical quench.** Some chemicals will affect the transfer of energy between the solvent and the fluorors resulting in reduction in the amount of light and a subsequent reduced counting efficiency.

2. **Colour quench.** Solid and liquid scintillators emit light in the blue region of the spectrum. Red, green and yellow colors in the counting vial absorb the light, resulting in reduced efficiency.

3. **Self Absorption.** This occurs when radiation emitted by an isotope remains undetected due to absorption of the radiation by the sample itself (e.g. in precipitates, cells).

D. QUENCH CORRECTION

All samples are quenched to some degree. The counts per minute observed (cpm) may differ substantially from the true radioactive decay rate, (disintegrations per minute, (dpm), depending on the efficiency of the counting process. The counting efficiency is by definition:

\[
\text{counting efficiency} = \frac{\text{cpm}}{\text{dpm}}
\]

therefore, \( \text{dpm} = \frac{\text{cpm}}{\text{counting efficiency}} \)

To determine the counting efficiency, the amount of quenching has to be known. Several methods are used to characterize and quantify the quenching for a particular sample. A common method uses the so-called “H-number” *proprietary technique by Beckman Instruments) which is assigned by an on-line analysis of the Compton electron spectrum generated in the sample by shining briefly an external standard source on this sample.

A quench calibration curve can be constructed by plotting the counting efficiency versus the H-number using a set of samples of known constant activity but containing varying amounts of quenching agent. In modern instruments, the quench curve can be stored in the machine’s electronic memory such that the quenching correction is made automatically to provide directly the output as dpm.
E. CHEMILUMINESCENCE

In some cases the sample may contain substances which can be excited by absorption of ambient light or other interactions. These excited states can have lifetimes in the 10’s of minutes and can relax by emitting light (chemiluminescence). Such occurrences, although unrelated to radioactive events, will translate into false high activity readings for the sample. Events due to chemiluminescence can be easily discriminated as they show up at very low energy. This phenomenon may occur when counting swipe test samples of dirty areas like floors, swipe test samples of some paints or inks, and samples that have a high or low pH. Recounting, dark adapting, or changing counting parameters is sometimes necessary to clarify the difference between true radioactivity and chemiluminescence.

F. STATIC ELECTRICITY

On occasion, spurious, non-reproducible counts will be observed. The cause may be static electricity. Handling of plastic scintillation vials with surgical gloves can build up a charge on vial. It is advisable not to wear gloves when loading the LS counter.

REFERENCES

1. Hawkins, E.F. Scintillation Supplies and Sample Preparation
   Donald L. Horrocks Nuclear Applications Laboratory Beckman Instruments, Inc.

APPENDIX X - Inventory Sheet Documentation

As a condition of the license at SFU, all isotopes must be accounted for from the moment they arrive at Science Receiving until they decay to background levels or are disposed of as waste. All shipments of radioactivity are received in the Hot Lab and issued a unique identifying number and an inventory sheet which allows tracking of radioisotope usage for a particular source. As a user of radioisotopes, it is your responsibility to document your usage, storage, transfer, generation of waste, and disposal of radioisotopes.

Sometimes, this process may seem unnecessarily arbitrary or cumbersome. But aside from the legal requirement, the process is ultimately to ensure accountability and your safety.

Enclosed are some completed sample inventory sheets for four separate scenarios as well as some completed waste tags used for labeling waste containers:

Scenario I - Routine Use of a P-32 labeled isotope for sequencing
Scenario II - Use of an I-125 Radioimmunoassay kit
Scenario III - Use of C-14 for labeling and storage of product for later analysis
Scenario IV - Transfer of radioisotope to an individual in another room on a different permit.

Sample Waste Tags

These scenarios cover the most frequent cases encountered. It may be that none of these fit exactly your situation. Please do not hesitate to contact Radiation Safety if you are not sure how this form applies to your particular use situation.
# Scenario I - P-32 Usage

**SIMON FRASER UNIVERSITY**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Room: SSB 6666</td>
<td>Half-life: 14.3 days</td>
<td>Amount (MBq): 37 MBq</td>
<td>Location: fridge</td>
<td>Volume(µL):100 µL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DATE VIAL SENT TO HOTLAB___________________**

<table>
<thead>
<tr>
<th>SOURCE USAGE (UNIT = µL)</th>
<th>WASTE BREAKDOWN (UNIT= %)</th>
<th>NEW PRODUCT INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
<td>USER</td>
<td>AMOUNT USED</td>
</tr>
<tr>
<td>Mar 12/96</td>
<td>Sharon</td>
<td>0</td>
</tr>
<tr>
<td>Mar 14/96</td>
<td>Yousef</td>
<td>2 µL</td>
</tr>
<tr>
<td>Mar 16/96</td>
<td>Henry</td>
<td>2 µL</td>
</tr>
<tr>
<td>Mar 21/96</td>
<td>Karen</td>
<td>3 µL</td>
</tr>
<tr>
<td>Mar 24/96</td>
<td>Andrea</td>
<td>3 µL</td>
</tr>
</tbody>
</table>

**REMARKS:** Concentration Activity = 0.37 MBq/µL
Scenario I - Isotope is removed twice a week for two weeks.

1. The units chosen for usage are µL. The concentration activity is noted under “Remarks.”

2. The unit chosen for waste is % of amount used.

3. At the end of week 1, the high level solid waste is packaged, labeled with a waste tag numbered #128. The waste is transferred to the Hot Lab, SSC-B7249.

4. At the end of two weeks, the high level solid waste is again packaged, labeled with a waste tag numbered #5166, and sent to the Hot Lab.

5. The low level solid waste is labeled with waste tag #312.

6. The aqueous waste container is labeled with waste tag #5155. The contents are sampled and measured by liquid scintillation counting and the activity noted on the waste tag, before transferring it to SSC-B7249.
B. Sample Waste Tags

<table>
<thead>
<tr>
<th>RADIOACTIVE WASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.D. # 5155</td>
</tr>
<tr>
<td>PERMIT HOLDER:</td>
</tr>
<tr>
<td>Smith</td>
</tr>
<tr>
<td>ROOM: SSB 6666</td>
</tr>
<tr>
<td>DATE: Mar. 16/96</td>
</tr>
<tr>
<td>✓ AQUEOUS LIQUID</td>
</tr>
<tr>
<td>✓ ORGANIC LIQUID</td>
</tr>
<tr>
<td>✓ LOW LEVEL SOLID</td>
</tr>
<tr>
<td>✓ HIGH LEVEL SOLID</td>
</tr>
<tr>
<td>✓ ANIMAL WASTE</td>
</tr>
<tr>
<td>✓ BIOHAZARD WASTE</td>
</tr>
<tr>
<td>ISOTOPE: P-32</td>
</tr>
<tr>
<td>ACTIVITY: 20,000 cpm/ml</td>
</tr>
</tbody>
</table>

Scenario I – How to determine % Waste
The only waste that we can easily measure with accuracy is the aqueous waste. We know that the original concentration of the source material is 37 MBq/100 µl. If we removed 2 µl from the source vial for our experiment, then the amount used in the first experiment was:

37 MBq/100 µl x 2 µl = 0.74 MBq.

To measure the activity of the aqueous waste, we remove a 1 ml solution and count it on the scintillation counter. In this case, a 1 ml solution had an activity of 20,000 counts per minute (20,000 cpm).

The total volume of aqueous waste is 1.5 litres.
1. Assuming that the liquid scintillation counting is 100% efficient, then the total activity present in the aqueous waste is:

1.50 l x 20,000 cpm/ml = 3 x 10^7 cpm

= 3 x 10^7 dpm

2. Convert dpm to dps:

3 x 10^7 dpm/ 60 per second = 5 x 10^5 dps

3. Convert dps to Bq:

5 x 10^5 dps = 5 x 10^5 Bq = 0.5 MBq

Therefore, the % activity in the aqueous waste is:

0.5 MBq/0.74 MBq x 100% = 68%.

4. Knowing accurately the activity of the aqueous waste and approximating the low level waste as ~2% allows us to estimate the activity present in the high level solid as:

100% - 68% - 2% = 30%.

5. The activity in the bag of high level solid waste is

~30% x 0.74 MBq = 0.222 MBq
C. Explanation Of Terms On Radioisotope Usage Sheet

SOURCE USAGE (UNIT = ).: Any convenient unit is acceptable (e.g. mCi, kBq, ml, µl, etc…). However, if units other than “activity” are used, indicate the specific activity under REMARKS; for example, if UNIT = ml, then indicate “Source is xx MBq/ml.”

DATE, USER: Any entry in a row must be date and the person entering the data must be identifiable.

AMOUNT USED/REMAINING: This refers to the quantity used (remaining) from (in) the source vial, expressed in the UNIT chosen above.

PROCEDURE: Enter a generic term for the procedure performed (e.g. iodination); if necessary, under REMARKS, present a more precise description of the PROCEDURE.

WASTE BREAKDOWN (UNIT = ).: UNIT may be activity or percent (%) of AMOUNT USED.

HIGH LEVEL, LOW LEVEL, AQUEOUS, ORGANIC: Consult Table VIII - Handling of Radioactive Waste to decide which headings are applicable

ID: This refers to the unique number which is located on the waste tag. Waste tags are available from the Hot Lab.

OTHER: Enter any waste amount not identified in the previous columns, e.g. carcass, xx MBq.

STORAGE LOCATION, AMOUNT STORED: Entries under these two items refer to the case where the PROCEDURE generates new radioactive products which are stored in a STORAGE LOCATION for further use.

RADIOACTIVE WASTE TAG: All bags and containers of waste which are transferred to the Hot Lab must be labelled with a Radioactive Waste Tag. Note that the actual amount or activity of isotope, not percentage of waste, must be recorded in the box marked: “ACTIVITY.”
### D. Scenario II - Use of an I-125 Radioimmuno assay kit

**SIMON FRASER UNIVERSITY**

- **Code:** I-125-789
- **Form:** cortisol kit
- **Permit Holder:** Parkhouse
- **Date:** Apr 4, 1996
- **Ref. Date:** May 5, 1996
- **Room:** K9615
- **Half-life:** 60 days
- **Location:** fridge
- **Volume (µl):** 100 µl
- **Amount (MBq):** 60 kBq
- **Cat. Number:** 07-2891-2

#### DATE VIAL SENT TO HOTLAB: Apr 23/96

<table>
<thead>
<tr>
<th>DATE</th>
<th>USER</th>
<th>AMOUNT USED</th>
<th>AMOUNT REMAINING</th>
<th>PROCEDURE</th>
<th>HIGH LEVEL SOLID</th>
<th>LOW SOLID</th>
<th>AQUEOUS LIQUID</th>
<th>ORGANIC LIQUID</th>
<th>OTHER</th>
<th>STORAGE LOCATION</th>
<th>AMOUNT STORED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 4/96</td>
<td>Sharon</td>
<td>0</td>
<td>50 tubes</td>
<td>RIA</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Apr 15/96</td>
<td>Silia</td>
<td>25 tubes</td>
<td>25 tubes</td>
<td>RIA</td>
<td>2 %</td>
<td>123</td>
<td>trace</td>
<td>98%</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Apr 22/96</td>
<td>Silia</td>
<td>25 tubes</td>
<td>0</td>
<td>RIA</td>
<td>2%</td>
<td>335</td>
<td>trace</td>
<td>98%</td>
<td>---</td>
<td>223</td>
<td>---</td>
</tr>
</tbody>
</table>

**REMARKS:** Activity = 1.2 kBq/tube
1. The unit chosen for usage is the number of tubes used; the CNSC prefers that the user note the number of tubes used rather than the actual quantity of isotope. Under “Remarks”, the activity/tube is noted.

2. The unit chosen for waste is %.

3. After the first run with 25 tubes, the tubes are packaged as high level solid waste, labeled with a waste tag numbered #123.

4. After using the remaining 25 tubes, the tubes are packaged as high level solid waste, labeled with a waste tag numbered #335.

5. The low level solid waste is packaged, labeled with a waste tag numbered #215.

6. The aqueous waste container is labeled with a waste tag numbered #223, sampled for activity, and the activity entered on the waste tag.

" The date the empty tubes and source vials are returned to the Hot lab is entered on the inventory sheet."
## Scenario III - Labeling and storage of product for later analysis

**SIMON FRASER UNIVERSITY**

- **Code:** C-14-1234
- **Form:** benzopyrene
- **Permit Holder:** Kennedy
- **Date:** Mar 14/96
- **Vendor:** NEN
- **Room:** B 7777
- **Volume (µl):** 1000
- **Cat. Number:** CFA 417
- **Volume:** 1000
- **Location:** freezer

### Date Vial Sent to Hotlab

<table>
<thead>
<tr>
<th>Date</th>
<th>User</th>
<th>Amount Used</th>
<th>Amount Remaining</th>
<th>Procedure</th>
<th>High Level ID</th>
<th>Low Level ID</th>
<th>Aqueous Liquid ID</th>
<th>Organic Liquid ID</th>
<th>Other</th>
<th>Storage Location</th>
<th>Amount Stored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar 14/96</td>
<td>Sharon</td>
<td>0</td>
<td>37 MBq</td>
<td>delivery</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.20 µCi, heart &amp; liver</td>
</tr>
<tr>
<td>Mar 16/96</td>
<td>Blair</td>
<td>1 µCi</td>
<td>999</td>
<td>injection of trout</td>
<td>-----</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>freezer, Alcan 108</td>
<td>0.50 µCi</td>
</tr>
<tr>
<td>Jun 16/96</td>
<td>Blair</td>
<td>---</td>
<td>---</td>
<td>analysis of frozen tissue</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.15 µCi</td>
<td>---</td>
<td>freezer, Alcan 108</td>
<td>0.30 µCi tissue homogenate</td>
</tr>
</tbody>
</table>

### Remarks:

1. The unit chosen for usage is µCi.
2. The unit chosen for waste is µCi.
The researcher wants to save the fish heart and liver, containing 0.20 µCi, in the freezer, for a later study.

Approximately 0.30 µCi muscle and skin is homogenized in saline and stored in the freezer for later analysis.

The rest of the fish carcass is wrapped and labelled with a waste tag, noting the total weight of the carcass and the activity present. The carcass is then taken to SSC-B7249, after prior arrangement, for storage.

On June 16, the frozen tissue homogenate prepared in March, is analyzed, generating 0.15 µCi aqueous waste and 0.15 µCi organic waste, in containers labeled #24 and #25, respectively.
Scenario IV - Transfer of radioisotope vial and contents to another permit

**SIMON FRASER UNIVERSITY**

<table>
<thead>
<tr>
<th>Code: H-3-5000</th>
<th>Form: thymidine</th>
<th>Permit Holder: Farrell</th>
<th>Bat. Number: H65432</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date: Mar. 22, 1996</td>
<td>Ref. Date: Apr 22, 1996</td>
<td>Date Ord'd: Mar 1, 1996</td>
<td>PO Number: S22222</td>
</tr>
<tr>
<td>Vendor: ICN</td>
<td>Half-life: 12.3 y</td>
<td>Amount (MBq): 9.25 MBq</td>
<td>Cat. Number: H678</td>
</tr>
<tr>
<td>Room: SSB 5000</td>
<td>Volume (µL): 250 µL</td>
<td>Location: freezer</td>
<td></td>
</tr>
</tbody>
</table>

**DATE VIAL SENT TO HOTLAB___________________**

<table>
<thead>
<tr>
<th>SOURCE USAGE (UNIT = MBq )</th>
<th>WASTE BREAKDOWN (UNIT= MBq)</th>
<th>NEW PRODUCT INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
<td>USER</td>
<td>AMOUNT USED</td>
</tr>
<tr>
<td>Mar 22/96</td>
<td>Sharon</td>
<td>0</td>
</tr>
<tr>
<td>Mar 25/96</td>
<td>Kurt</td>
<td>0.37</td>
</tr>
<tr>
<td>Mar 27/96</td>
<td>Ian</td>
<td>0.74</td>
</tr>
<tr>
<td>Apr 4/96</td>
<td>Ian</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Remarks:
After using 0.37 MBq, the high level solid waste is packaged and labelled with waste tag #266.

The organic waste is packaged and labelled with waste tag #183 and sampled using liquid scintillation counting to determine the activity, which is also entered on the waste tag.

The vial and remaining contents are given to another lab; this is indicated as a transfer. The new location of the vial is noted on the inventory sheet. The inventory sheet stays with the vial, until the vial is returned to the Hot Lab.
APPENDIX - XI Record Keeping

A. Records maintained by Radiation Safety Staff
The Program Manager, Ionizing Radiation Safety is responsible for ensuring that the following records are maintained:

- leak tests
- record of decommissioning of labs
- inventory of sources
- record of usage
- swipe tests
- waste disposal
- transfer of sources
- transport of sources
- personal exposure
- list of Nuclear Energy Workers
- calibration of monitors
- list of approved users
- list of approved rooms and their laboratory classification
- training of users
- incidents, accidents, and spills
- inspections

B. Records maintained by the User
The following documents are required to be available in the primary approved location (ie. the laboratory of field site):

- Inventory sheets for record of use and waste stream tracking
- Swipe test records

C. Note that no records may be disposed without 90 day prior, written notification of the CNSC.