Radiation Safety Manual

Original 2010

Revised April 2013
Revised February 2018
Revised March 2023

Western Canadian Universities Marine Sciences Society
Bamfield Marine Sciences Centre
Occupational Health and Safety

Emergency Contact Numbers

Institution	Primary Contact	Secondary Contact
Fire, Police, Ambulance	911	
Hazardous Materials Response	911	
Radiation Safety Officer	Ext. 255	VHF Ch 9
Forest Fire	1-800-663-5555	
Bamfield Red Cross Outpost	(250) 728-3312	VHF Ch 82
Emergency First Aid	(250) 720-1433	
Bamfield Coast Guard	(250) 728-3322	VHF Ch 16
West Coast General Hospital – Port Alberni	(250) 731-1370	
RCMP Port Alberni	(250) 723-2424	
Emergency Program (24 hrs)	1-800-663-3456	
Rescue Centre	1-800-567-5111	(cell #727)
Poison Control	1-800-567-8911	

Bamfield Marine Sciences Centre

Position	Primary Contact	Secondary Contact
Director	(403) 473-3498	
Managing Director	Ext. 212	
Operations Manager	Ext. 215	
Head of Research Services / RSO	Ext. 255	(604) 868-1465
Research Coordinator	Ext. 229	
Education Manager	Ext. 229	
Dive & Safety Officer	Ext. 222	VHF Ch 9
First Aid Attendant	(250) 720-1433	VHF Ch 9
Switchboard	Ext. 221	(250) 728-3301
Facility Operations	Ext. 272	
After Hours		
Managing Director	Ext. 240	
Operators Manager	Ext. 215	
Head of Research Services	(604) 868-1460	
Radiation Safety Officer	(604) 868-1460	
First Aid Phone	(250) 720-1433	

Forward

Nuclear substances and radiation devices are used throughout Canada for a wide variety of purposes, including: medicine, research, teaching, defense, and power. While radiation sources represent a minimal risk to personnel when properly handled, accidents and misuse can lead to health and environmental hazards. These potential hazards have led to the formation of the Canadian Nuclear Safety Commission (CNSC also formally known as the Atomic Energy Control Board). The CNSC regulates all aspects of the use, handling, transport, and safety of radioactive material in Canada. The Commission has issued a "Nuclear Substance and Radiation Device License – Use Type 813 "for labs" to the Bamfield Marine Sciences Centre (BMSC), which requires BMSC to adhere to, and enforce, all of the regulations and guidelines of the Nuclear Safety and Control Act. BMSC has developed a Radiation Safety Program that not only takes the CNSC regulations and guidelines into account, but also seeks to prevent harm to human health and the environment.

Accidents and misuse can lead not only to radiation exposure of researchers, but also to the loss of valuable scientific information. It is essential therefore to have a good understanding of the principles of radiation protection, handling, and storage, in order to minimize the likelihood of such events.

After reviewing the BMSC Radiation Safety Manual, individuals will have a strong foundation in these principles as well as the tools and knowledge to evaluate and deal with any hazardous situations that may arise.

This manual has been developed with the mandate, principles and safety practices of the Bamfield Marine Sciences Centre in mind. Stress has been put upon the safe handling and storage techniques that will help to maintain a safe and pristine environment. The knowledge of Radiation Safety Officers from the member universities have gone into this manual. It therefore has the endorsement of the member universities: the UBC Committee on Nuclear substances and radiation devices and Radiation Hazards, the University of Victoria's Radiation Health and Safety in Research Committee, the Simon Fraser University's Committee on Radiation Safety, and BMSC's Health and Safety Committee.

BMSC Radiation Safety Officer
2010
Revised April 11, 2013; April 14, 2018; March 6, 2023

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1. ADMINISTRATIVE REQUIREMENTS

1.1 Administration of the Bamfield Marine Sciences Centre

The Bamfield Marine Sciences Center (BMSC) is located on the west coast of Vancouver Island, British Columbia (BC), within the traditional territory of the Huu-ay-aht First Nations in the remote community of Bamfield, on Barkley Sound. BMSC was established in 1972 to create a national facility capable of supporting diverse coastal and marine research of the highest caliber. Operated by a not-for-profit consortium of five western Canadian universities (Simon Fraser University, University of Alberta, University of British Columbia, University of Calgary, and University of Victoria), BMSC supports over 200 national and international researchers and several hundred undergraduate students annually. Our vision is to facilitate *Life changing exploration and discovery in coastal and marine environments* and our values are focused on *partnership*, *scholarship* and *stewardship* of the environment.

BMSC promotes and encourages environmentally responsible research. By striving to minimize our impact, and promoting the overall good health of the environment, our goal is to ensure that local ecosystems will be as pristine tomorrow as they are today.

1.2 Safety Policy

The safety of all visitors to BMSC is a major concern of the Western Canadian Universities Marine Sciences Society (WCUMSS). It is an objective of the Society to provide a beneficial environment for scientists and students to work and learn together.

To this end, BMSC is administered so as to ensure that health, safety, and accident prevention form an integral part of the design, construction, purchase, and maintenance of all buildings, equipment, and work processes.

The BMSC's Health and Safety Committee shall work to achieve these objectives. Each department shall monitor the safety programs within their areas and make recommendations to improve the effectiveness with which the safety objectives of WCUMSS can be achieved.

Compliance with the Workers' Compensation Act of British Columbia, the Canadian Council on Animal Care Guidelines, the Nuclear Safety and Control Act, and the Canadian Nuclear Safety Commission's Rules and Regulations involving the use of nuclear substances and radiation devices are the minimum standards that are acceptable to WCUMSS and the BMSC. The intention is to encourage all staff, faculty, and students to strive to exceed these minimum legal standards.

1.3 Personal Responsibilities

The successful application of this policy will be achieved by everyone exercising their personal responsibility for safety as follows:

1.3.1 The WCUMSS and Bamfield Marine Sciences Centre

It is the responsibility of WCUMSS and BMSC acting through the director and senior managers to:

- provide a safe and healthy working environment;

- ensure regular inspections are made and take action as required to improve unsafe conditions;
- provide first aid facilities and knowledge where appropriate;
- support supervisors and safety committees in the implementation of an effective accident prevention program;
- provide leadership and instruction in the implementation of an effective emergency response program for natural disasters;
- ensure compliance with all WCB, CCAC, and CNSC acts and regulations.

1.3.2 Departmental Managers / Coordinators

It is the responsibility of the department managers and coordinators to:

- formulate specific safety rules and safe work procedures for their specific areas of supervision;
- ensure that all employees under their supervision are aware of safety practices and follow safety procedures;
- provide training in the safe operation of equipment;
- regularly inspect their areas for hazardous conditions;
- investigate and report any accidents using the appropriate forms;
- be involved with the BMSC Health and Safety Committee;
- observe and enforce all WCB, CCAC, and CNSC acts and regulations.

1.3.3 BMSC Employees

It is the employee's responsibility to:

- observe safety rules and procedures established by BMSC, WCUMSS, the WCB, CCAC, and the CNSC;
- take an active part in practicing safe work habits;
- immediately report any accident, injury, or unsafe conditions to a supervisor;
- properly use and care for personal protective equipment provided by BMSC.

1.3.4 Faculty and Researchers

It is the responsibility of the Faculty and Researchers to:

- formulate specific safety rules and safe work procedures for their specific areas of supervision;
- ensure that all employees under their supervision are aware of safety practices and follow safety procedures;
- ensure that all employees under their supervision receive training in the safe operation of equipment;
- regularly inspect their areas for hazardous conditions and report any findings;
- observe safety rules and procedures established by BMSC, WCUMSS, the WCB, CCAC, and the CNSC;
- take an active part in practicing safe work habits;
- immediately report any accident, injury, or unsafe conditions to a BMSC staff member;

- properly use and care for personal protective equipment provided by BMSC.

1.3.5 Students

It is the students' responsibility to:

- observe safety rules and procedures established by BMSC, WCUMSS, the WCB, CCAC, and the CNSC;
- take an active part in practicing safe work habits;
- immediately report any accident, injury, or unsafe conditions to a BMSC staff member;
- properly use and care for personal protective equipment provided by BMSC.

2. DUTIES AND RESPONSIBILITIES

Federal legislation created The Nuclear Safety and Control Act and the pursuant regulations, which deal with the handling of radioactive material in Canada. The Canadian Nuclear Safety Commission (CNSC) is the federal body whose agents administer the Act. The Commission has issued a "Nuclear Substance and Radiation Device License – for Laboratory Studies (use Type 813)" at BMSC, and has defined the duties and responsibilities of the BMSC Radiation Safety Committee (RSC), which administers the license.

These responsibilities include ensuring that all persons involved in the handling of nuclear substances and radiation devices have adequate training and experience enabling them to perform their duties safely and in accordance with the licensee's radiation safety program and CNSC requirements. Further, the committee is required to ensure that appropriate equipment and facilities exist and are in compliance with CNSC requirements.

The committee is also required to ensure that the doses of ionizing radiation received by any person involved in the use of nuclear substances and radiation devices do not exceed the limits specified in the Canadian Nuclear Safety and Control Act and Regulations.

The BMSC radiation safety program is based on the principle that radiation exposure and the associated risk must always be As Low As Reasonably Achievable (ALARA). The ALARA principle is subject to the condition that all exposures must not exceed the regulatory limits.

Further, the policy implies that simply meeting the regulatory limits is not adequate and that every reasonable effort must be made to reduce or eliminate radiation exposure.

The committee is also permitted to grant approval for use of nuclear substances and radiation devices to users only if the use complies with all the regulatory, environmental, and institutional requirements. The committee can ultimately deny the use of nuclear substances and radiation devices with sufficient cause.

The CNSC also defines the roles and responsibilities of the permit holders and nuclear substances and radiation devices users as well as the Radiation Safety Officer (RSO).

In general terms: The permit holders are personally responsible for radiation safety in all the areas specified on their permits; users of nuclear substances and radiation devices are personally responsible for the safe handling of nuclear substances and radiation devices, and the RSO is responsible for coordinating and overseeing all aspects of radiation safety within the institution.

2.1 Specific Responsibilities of the Bamfield Marine Sciences Centre

BMSC can best ensure ionizing radiation sources are handled safely, by incorporating the active participation of all faculty, management, staff, and students in the radiation safety program. In specific situations, the respective contributions of these parties will depend upon regulatory requirements, organizational structure, and the mandate and responsibilities of management, staff, and students.

Licensees must, by law, ensure that they and those activities under their control, comply with any applicable regulations and license conditions. The federal government only licenses entities that have legal capacity and responsibility; that is, individuals, companies, or institutions. When a nuclear substances and radiation devices license is granted to an educational or research institution, it issues the license to the organization. Upon licensing, the institution becomes and remains legally responsible for compliance within the terms of the license and any other regulatory requirements.

BMSC has chosen to delegate, in whole or part, some of these duties to the Radiation Safety Committee (RSC) and Radiation Safety Officer (RSO).

2.2 Composition and Duties of the BMSC Radiation Safety Committee

The Committee includes BMSC staff members (including the RSO), and users that use nuclear substances for their research. Collectively, these members advise BMSC management on radiation safety matters in general, and the effectiveness of the Radiation Safety Program at BMSC.

As authorized by WCUMSS and the BMSC Director, the Committee may:

i. Oversee radiation safety on behalf of the Society;
ii. Advise management and the RSO on radiation safety matters, including the safe use of nuclear substances and radiation devices during licensed activities;
iii. Review the proposed or existing Radiation Safety Program and procedures to determine whether they assure that radiation exposures will comply with regulatory limits and will be As Low As Reasonably Achievable (ALARA), as described in the Regulatory Guides;
iv. Review all proposed uses of nuclear substances and radiation devices, and their proposed locations of use, to determine whether these proposals comply with corporate procedures and regulatory requirements;
v. Assess the adequacy, in terms of the contents and schedules for delivery, of the institution's program to train staff and workers in the safe use of nuclear substances and radiation devices;
vi. Assess the results, and determine the effectiveness, of the institution's program to train staff and workers in the safe use of nuclear substances and radiation devices;
vii. Review the results of internal inspections of facilities, premises, equipment, and work practices that assess whether nuclear substances and radiation devices are used safely in CNSC-licensed activities;
viii. Review annual summaries of the occupational radiation exposures received by staff and workers to determine whether these exposures comply with the ALARA principle of dose limitation;
ix. Review reports concerning any incidents or unusual occurrences at the institution that involved nuclear substances and radiation devices;

x. Recommend corrective measures or improvements when a review or assessment identifies deficiencies in a proposal, program, practice, procedure, equipment, record or report;
xi. Recommend measures or improvements to prevent recurrences of any incidents that exposed staff or workers to excessive radiation, or to prevent recurrence of any other unusual occurrences involving nuclear substances and radiation devices;
xii. Advise management of any perceived need for additional resources to establish, maintain or improve the Radiation Safety Program; and
xiii. Maintain written records of their activities, decisions, advice and recommendations concerning radiation safety, including details of meetings and reviews of data, reports, programs, procedures, circumstances, incidents or unusual occurrences.

2.3 Duties of the Radiation Safety Officer

The RSO has been assigned by the BMSC Director, lead responsibility to ensure radiation safety at all research and educational sites over which WCUMSS has administrative control.

To ensure radiation safety and compliance with regulatory requirements on behalf of WCUMSS and BMSC, the RSO is authorized to do the following:

i. Supervise, advise, and consult regarding issues related to BMSC’s use of nuclear substances and radiation devices in accordance with regulations and license conditions;
ii. Prepare annual reports in accordance with Regulatory Documents, and any pertinent conditions contained in the nuclear substances and radiation devices license issued to BMSC;
iii. Review, either independently or in concert with the RSC, all client requests for authorization to purchase or use radioactive materials in order to ensure that the proposed uses and locations of use are acceptable and comply with the Regulations and license requirements;
iv. For radioactive materials, authorize only those purchases, uses, work, procedures, and conditions and locations of use that assure compliance with BMSC’s Radiation Safety Program, the Regulations, and license;
v. Assess and designate, as “Basic-level” or “Decommissioned” in accordance with license conditions, the BMSC laboratories that use nuclear substances and radiation devices;
vi. Maintain a record of all BMSC laboratories that use radioactive materials, and whether they are designated as Basic-level or Decommissioned;
vii. Develop and implement administrative controls or procedures to ensure radiation safety and compliance with regulatory requirements;
viii. Assess the qualifications and competence of persons who apply to use or handle radioactive materials to determine whether they can do so safely and in compliance with regulations and license;
ix. Ensure that a Radiation Safety Program appropriate to BMSC’s undertakings are developed, implemented, and maintained;

x. Ensure that persons who are required to use or handle radioactive materials are adequately trained in radiation safety and BMSC's radiation protection procedures;
xi. Authorize only qualified persons to possess, use or handle radioactive materials;
xii. Authorize and undertake, on an as-required basis, the safe disposal of radioactive materials in accordance with applicable regulations, procedures, and license conditions;
xiii. Designate Nuclear Energy Worker's (NEW's) in accordance with Section 17 of the Regulations;
xiv. Assess, independently or in conjugation with management or the RSC, the effectiveness of the Radiation Safety Program;
xv. Ensure that workers such as porters, cleaners, secretaries, and shipping and receiving or other support staff, who may be exposed to radiation as a consequence of their duties, receive appropriate training in radiation safety;
xvi. Develop and implement programs to inspect and critically review licensed activities, locations of nuclear substances and radiation devices use, storage of nuclear substances and radiation devices, and the adequacy of personnel training, safety procedures or physical facilities;
xvii. Implement remedial actions to correct any deficiencies identified in the inspection programs referred to in xvi. above;
xviii. Initiate any revisions to procedures, changes to equipment and facilities, and license amendments required to ensure, on an ongoing basis, that BMSC's operations, equipment and facilities comply with regulatory requirements;
xix. Communicate with the RSC, nuclear substances and radiation devices users, and management;
xx. Design and implement in accordance with regulatory requirements, appropriate personnel monitoring to measure exposures to ionizing radiation;
xxi. Administer or control the issue, use, and maintenance of personnel monitoring devices and equipment within BMSC, and the recording results;
xxii. Monitor the occupational radiation exposures received by employees by reviewing the records of exposures over each calendar quarter;
xxiii. Where the above reviews of radiation exposure records indicate that exposures are unnecessarily high, recommend measures to management to reduce these exposures in accordance with the ALARA principle of dose limitation, as described in Regulatory Documents;
xxiv. Investigate all reports of overexposures to ionizing radiation, of accidents involving radioactive materials, and of losses of radioactive materials, determine pertinent facts or confirm events, and recommend appropriate actions to mitigate the consequences or to prevent recurrences;
xxv. Ensure that the incidents referred to in (xxiv.) above, and the results of related investigations, are reported in accordance with the Regulations;
xxvi. Assess the adequacy of survey programs that measure or control radiation fields and radioactive contamination during licensed activities, such as the use, storage, and disposal of nuclear substances and radiation devices;

xxvii. Ensure, through participation or other measures, that properly-designed radioactive-decontamination programs are implemented as required in the interests of radiation safety;
xxviii. Ensure that sealed radiation sources are leak-tested in accordance with the BMSC's procedures and regulatory requirements;
xxix. Ensure that all persons who use or handle nuclear substances and radiation devices follow BMSC procedures, in order to prevent occupational exposures to ionizing radiation that exceed the limit specified in the Regulations or that violate the ALARA principle of dose limitation;
xxx. Prepare or review proposed or existing radiation safety procedures, either independently or in cooperation with the RSC;
xxxi. Coordinate, or participate in, emergency responses to accidents involving radioactive materials;
xxxii. Ensure that all records and reports that are required by the conditions of the nuclear substances and radiation devices license and the Regulations are prepared, maintained and submitted as required; and
xxxiii. Ensure that any nuclear substances and radiation devices that are to be transported over public roads are packaged in accordance with the Transport Packaging of Radioactive Materials Regulations.

2.4 Duties of Authorized Investigators

i. Ensure that the conditions stated in the BMSC license are fulfilled and that safe laboratory practices are followed;
ii. Ensure that all staff and students under their supervision have been authorized to use those nuclear substances and radiation devices. An up to date list of all such personnel shall be maintained;
iii. Ensure that if required, all personnel using nuclear substances and radiation devices have been issued, and wear, a thermoluminescent or an optically stimulated luminescence dosimeter and participate in bioassay programs that may be required;
iv. Designate specific work and storage areas for nuclear substances and radiation devices and ensure that these areas are kept clean, are properly labeled, have adequate ventilation, and are adequately shielded;
v. Ensure that all personnel using nuclear substances and radiation devices have received adequate radiation protection training from their institution and have been informed of the risks associated with exposure to ionizing radiation. Further, authorized Investigators are responsible for the provision of specific training in nuclear substances and radiation devices handling that is necessary for the safe use of the nuclear substances and radiation devices in their laboratories;
vi. Maintain inventories of all nuclear substances and radiation devices purchased and used as well as storage and disposal records;
vii. Maintain all area monitoring and wipe test records; and
viii. Report all radiation incidents to the Radiation Safety Officer.

2.5 Duties of Authorized Users

i. Every person shall take all reasonable and necessary precautions to ensure their own safety and the safety of fellow workers; and
ii. Every person shall strictly adhere to all policies and procedures defined by all CNSC acts and regulations, WCB acts and regulations, and the WCUMSS Radiation Safety Policy as described in this Manual.

2.6 Duties of BMSC Staff

i. BMSC staff (porters, cleaners, secretaries, and shipping and receiving or other support staff) that by virtue of their duties may come into areas where licensed Nuclear Substance and Radiation Devices activity is permitted, or may come into contact with radioactive materials (e.g. a Transport of Dangerous Goods—Class 7 packages) will consult with the BMSC RSO. It is suggested that these individuals complete BMSC Radiation Safety Training, renewable on a 3- year basis.
ii. Every person shall strictly adhere to all policies and procedures defined by all CNSC acts and regulations, WCB acts and regulations, and the WCUMSS Radiation Safety Policy as described in this Manual.

3. USE OF NUCLEAR SUBSTANCES AND RADIATION DEVICES AT BMSC

3.1 Authorization to Use Nuclear substances and Radiation Devices at BMSC

Any Principal Investigator wishing to use nuclear substances and radiation devices in research or education conducted at BMSC must possess a nuclear substances and radiation devices license from the CNSC. Foreign researchers wishing to use nuclear substances and radiation devices in research or education at BMSC must provide evidence of their authorization to possess nuclear substances and radiation devices in their home country and complete BMSC Radiation Safety training (see 3.7 below). The BMSC RSO may then issue a Nuclear Substances and Radiation Devices permit to the researcher, for the laboratories specified under the BMSC Laboratory Studies Nuclear Substance and Radiation Devices License. The Principal Investigator and his/her laboratory personnel must also possess a certificate from a recognized Radiation Safety Course from his/her institution within the last 3 years, and provide documented evidence of that training. BMSC Radiation Safety Training and certification may be completed if prior training has lapsed or such training has not been previously conducted.

The Principal Investigator should request authorization to work with nuclear substances and radiation devices at BMSC via email with the BMSC RSO, including the proposed research and nuclear substances and radiation devices to be used, period of use, a copy of the Investigator's full license that has been issued by their home institution, and a copy of the Investigator's training certificate.

3.2 Amending Authorization to Use Nuclear substances and Radiation Devices at BMSC

An amendment to any of the defined conditions of authorization to use nuclear substances and radiation devices at BMSC must be approved by the Radiation Safety Committee or RSO. A request must be made in writing indicating the specific changes that are being requested. The authorization must be amended **PRIOR** to any changes being instigated by the researcher.

3.3 Termination of Authorization to Use Nuclear substances and Radiation Devices at BMSC

When a Researcher acquires authorization to use nuclear substances and radiation devices at BMSC, they accept personal responsibility for all associated activities. Unless a defined period of use was originally requested, this extends to ensuring that when nuclear substances and radiation devices are no longer needed or the researcher wishes to terminate his/her authorization, that the approved protocol is followed. If the Researcher plans to leave BMSC for a period of 4 months or longer, he/she must notify the RSC via the RSO.

<u>The Departing Authorized Principal Investigator **Will** Liaise with the RSO to Provide:</u>

1) Memo stating intent to discontinue the use of nuclear substances and radiation devices at BMSC unless a defined period of use was previously requested.
2) A complete set of wipe tests for all licensed laboratories used during his/her activities.
3) Record of proper disposal of radioactive substance on hand. This can include a gift of remaining radioactive substance to another researcher who is licensed for the nuclide, or transfer to another license.
4) Completion of a nuclear substances and radiation devices inventory, denoting usage, disposal and contamination control records.

Following the completion of the above steps, the Radiation Safety Officer will issue a letter to the researcher stating that they are no longer authorized to use nuclear substances and radiation devices at BMSC.

3.4 Reactivation of Authorization

If the researcher returns to BMSC within 12 months of their last visit and wishes to use nuclear substances and radiation devices at BMSC, he/she may apply to the RSO for reactivation of authorization - referring to the previous authorization and activities.

3.5 Annual Reports

At the end of each calendar year, the CNSC requires that the RSO submit a comprehensive report of all the activities related to the nuclear substances and radiation devices Safety Program. This annual report must conform in structure and content to specific criteria. Therefore, a summary of radioactive material purchased, disposed, and held in the inventory must be submitted to the Radiation Safety Officer by January 31 of each year.

3.6 Decommissioning a Laboratory

When BMSC no longer wishes to use a specific laboratory for the use of nuclear substances and radiation devices, the RSO must inform the RSC and:

1) Remove all nuclear substances and radiation devices from the laboratory.
2) Thoroughly clean the laboratory space and equipment with appropriate cleansers
3) Perform a complete set of wipe tests for the licensed laboratory no longer intended for use.
4) Remove all radiation labels and posters from the laboratory
5) Inform CNSC by letter of intent to decommission the laboratory including the results of wipe tests for that lab.

3.7 Radiation Safety Training

There are two broad categories of radiation safety training at BMSC; Researchers who are actively working with radionuclides and radiation devices as part of their research program and BMSC support staff (e.g. housekeeping, facilities, animal care, etc.). The primary RSO and Secondary RSO have additional training requirements that must be completed externally at institutes recognized by the CNSC for such training; they are not included in this description.

3.7.1 Researcher Training

Researchers from member universities who are working at BMSC under permit issued on their institutional CNSC licence, must provide a copy of their current (issued within the previous 3 calendar years) Radiation Safety Training certificate, or the BMSC RSO must confirm with member university's RSO that such training has been completed. Note: the BMSC Radiation Safety Manual was originally developed with input from the RSOs at the WCUMSS member universities, so there is a high degree of similarity between our various programs.

Principal Investigators (Researchers) from other Canadian Universities, Colleges, etc. who wish to work with radionuclides and radiation devices at BMSC must be licensed by the CNSC for such activity at their home institutions. The BMSC RSO will accept current Radiation Safety Training certificates for these researchers (and their staff; Post Docs, Graduate Students, Undergraduate Students) as proof of training, after consultation with the RSO of PIs home institution and review of the content of their training Program.

Authorized Principal Investigators from foreign countries (see 3.1) must take BMSC radiation safety training as described below, or provide a current certificate of training from a recognized Canadian Institution (e.g. University, Radiation Safety Institute of Canada) whose program has been reviewed by the BMSC RSO.

3.7.2 BMSC Staff Training

Due to the nature of the radionuclides used at BMSC (limited quantities, low activities of open source radioisotopes) is us unlikely that BMSC staff will encounter any potentially hazardous exposures in the course of their day to day routines. Additionally, the RSO (secondary RSO) has historically managed contaminated lab wastes and lab cleanup, when researchers are utilizing radioactive materials in the labs, which further reduces the likelihood of contamination. This said, Radiation Safety Training is recommended for BMSC staff who may work in and around the labs certified for Basic Use of Unsealed Nuclear Substances (currently the COTC wet lab, EcoPhys Lower North, Lower South and Upper South labs). The BMSC

RSO (or Secondary RSO) can provide training to staff upon request. This training, on an individual or group basis, will entail the following:

1. The RSO will provide the candidate(s) a copy of this RSM.
2. The RSO and the candidates will then work through the content of the RSM. This may be supplemented with additional materials such as Power-point Presentations, demonstration of survey meters, liquid scintillation counter, swipe testing methods, etc. or other teaching aids.
3. At the completion of the exercise, the candidates will be quizzed by the RSO, until the RSO is confident in their understanding and ability to follow the RSM.

4. INTRODUCTION TO MANUAL

The purpose of this manual is to assist in preparing BMSC staff, researchers and students to work safely with nuclear substances and radiation devices. The topic areas covered are as follows: an introduction to ionizing radiation, health effects, record keeping, legal requirements, practical aspects of handling nuclear substances and radiation devices, laboratory and personnel decontamination, the appropriate use of portable survey meters, and emergency response measures.

The primary objective of the BMSC Radiation Safety Manual, as a living document, is to ensure the safe and knowledgeable use of nuclear substances and radiation devices in research, and teaching.

5. FUNDAMENTALS OF PHYSICS

5.1 Historical Review

When the earth was formed, much of the physical matter was radioactive. Over the millennia, this activity has decayed until only those isotopes with extremely long half-lives and their decay products are found in the earth. Most of the radioactive material that is used in scientific research and medicine is generated in particle accelerators and/or nuclear reactors.

We are continually exposed to atomic radiations from the earth and are bombarded with different types of radiations emanating from the sun, stars, and galaxies. As cosmic radiation enters our atmosphere, it generates radioactive atoms, such as carbon-14 and hydrogen-3that become incorporated into our water and food supplies.

Life on earth has evolved in this inescapable bath of naturally occurring radioactivity and all living organisms, including humans, assimilate this material into their basic chemical make-up. Although ionizing radiation has been present from the beginning of time, it was not until the year 1895 that Wilhelm C. Roentgen discovered X-rays. Interest in this “new ray” was immediate and intense. Within a few months the first cases of injury due to radiation overexposure (erythema, skin burns, aplastic anemia) were seen by physicians, who knew neither about the origin of these injuries nor of any appropriate therapeutic response.

Within a year after Roentgen’s discovery of X-rays, Henri Becquerel discovered that uranium salts emitted radiation capable of exposing photographic films. In 1898, the element Polonium was isolated from tons of ore by Marie and Pierre Curie. Intensive research then followed, resulting in the isolation of the radioactive element radium and the discovery, and subsequent investigation, of alpha particles. The labs in which this research was performed were highly contaminated with radium, as up to a gram of the material was used in some instances.

> *Marie Curie and her husband Pierre are remembered for their pioneering discovery of, and experiments with, radium. Their extensive work with the radioactive element eventually cost them their lives. The books in which they recorded their notes remain radioactive to this day.*

Some of the initial health effects of radiation exposure were skin burns, deformed fingers, and cancer. One group of occupationally exposed workers were women employed in the 1920s as watch dial painters. In the process of their work, they ingested small amounts of radium, causing many to die from various types of radiation-induced cancers.

The first organized step toward radiation protection standards was made in 1915 at the first meeting of the British Roentgen Society. A resolution was passed that "...this Society considers it a matter of greatest importance that the personal safety of the operators conducting the roentgen-ray examinations should be secured by the universal adoption of stringent rules...". In 1928, at the Second International Congress of Radiology, the International Committee on X-Ray and Radium Protection (now known as the International Commission on Radiological Protection - ICRP) was formed. Early efforts of the ICRP were concerned with establishing radiation units and making some interim protection recommendations. Today the ICRP conducts in-depth studies of the many facets of radiation protection, makes recommendations, and issues reports, which form the basis for legislation worldwide. In Canada, the federal legislation governing radioactivity is the Nuclear Safety and Control Act, which is enforced by the Canadian Nuclear Safety Commission. Radiation emitting devices such as X-ray machines, microwave ovens, etc. are regulated by Health and Welfare Canada.

5.2 Atomic Structure

In spite of years of intense theoretical and experimental work, no completely satisfactory model of the atomic nuclear structure has been developed. Many models have been proposed, each capable of explaining some, but not all, of the physical characteristics of the atom and the nucleus. Even the most acceptable of the proposed structures are incomplete and research is constantly posing new questions and finding answers to the basic structure and substance of matter.

For our purposes, Bohr's Model of the atom adequately describes the atomic structure. It refers to a simple solar system-like model, with the negative electrons revolving about the positively charged nucleus (Fig. 1).

The nucleus is the central core of the atom and is composed of two types of particles, the proton and the neutron. The proton has a positive charge, while the neutron is electrically neutral. The mass of each neutron and proton is approximately one atomic mass unit (amu) and is equal to 1/12 of a carbon-12 atom (1.66×10^{-24}g).

Electrons revolve around the nucleus at discrete and well-defined orbital distances. Each electron carries a negative electrical charge and has a mass equal to 1/1836 that of a proton. There are 118 named elements, each of which is characterized by two related terms.

A = *mass number*, equal to the sum of protons and neutrons in the nucleus.
Z = *atomic number*, equal to the number of protons in the nucleus; Z is also equal to the number of electrons attached to the nucleus in a neutral, non-ionized atom.

Atomic Formula = ${}^{A}_{Z}X$
(Atom is unstable if [A-Z] > 3)

Given that the number of protons, and hence the atomic number, defines a specific type of atom, the number of neutrons may change without changing the chemical characteristics of that atom. Thus, various species or nuclides can exist with the same atomic number. These nuclide variants are called isotopes and are defined as nuclides having equal numbers of protons but different numbers of neutrons. Isotopes are atoms of the same element that have the same atomic number (Z), but a different mass number (A). An element may have many isotopes, a few of which are normally stable, but most are radioactive. However several elements, such as thorium, uranium, and plutonium, have no stable isotopes.

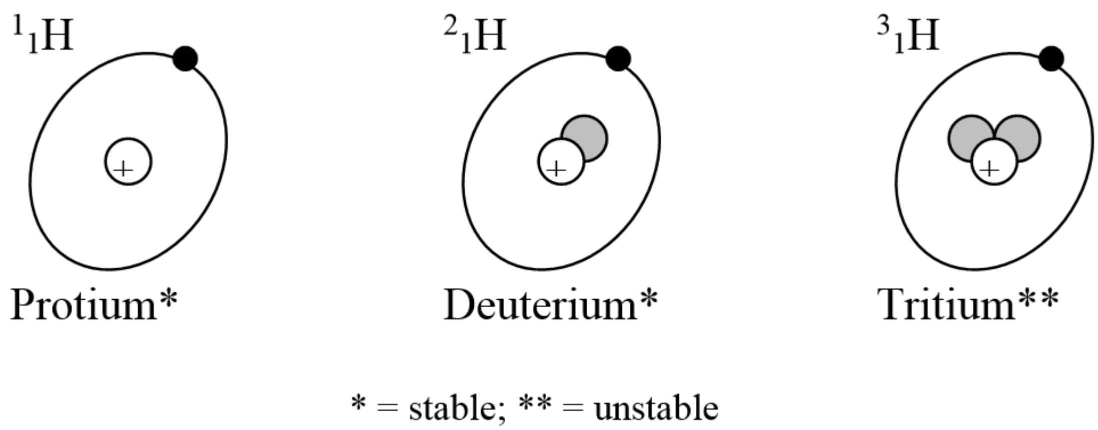

Figure 1. Isotopes of Hydrogen

5.3 Radioactivity

Radioactivity can be defined as spontaneous nuclear events that result in the atomic transmutation from one element into a different element. Many distinct mechanisms are involved in these nuclear transformations, of which alpha particle emissions, beta particles and positron emissions, and orbital electron capture are some examples. These reactions may or may not be accompanied by emission of gamma radiation. The exact mode of radioactive transformation depends on two factors:

- the particular type of nuclear instability (too high or too low neutron to proton ratio).
- the mass-energy relationships between the parent nucleus, progeny nucleus, and the emitted particle.

5.3.1 Alpha Emission

An *alpha particle* (α) is a massive, highly energetic nuclear fragment that is emitted from the nucleus of a radioactive atom when the neutron to proton ratio is too low. It is a positively charged helium nucleus, consisting of two protons and two neutrons.

Alpha Decay Formula
${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + \alpha^{4}_{2}$ + gamma rays
Ex: ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + \alpha^{4}_{2}$ + gamma rays

Alpha particles are extremely limited in their ability to penetrate matter due to their mass and charge. The dead outer layer of skin covering the entire body is sufficiently thick to stop and absorb all alpha radiation. As a consequence, alpha radiation from sources outside the body does not represent a radiation hazard. However, cells irradiated by alpha particles emitted by atoms that have entered the body by injection, ingestion, or inhalation can suffer severe radiation effects and are likely to be permanently damaged. Hence alpha radiation is an extreme internal radiation hazard.

Alpha particles are extremely hazardous when deposited internally; however the inability to penetrate clothing or the dead surface layer of skin minimizes the risk of external exposure to alpha radiation.

5.3.2 Beta Emission

A *beta particle* (β^-) is an electron that is ejected from a beta-unstable radioactive atom. The particle has a single negative electrical charge (-1.6×10^{-19} C) and a very small mass (0.00055 amu). The beta particle, or *negatron*, is emitted at the instant a neutron undergoes transformation into a proton. Beta decay occurs among those isotopes that have a surplus of neutrons.

Beta Decay Formula
${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + \beta^-$ + antineutrino
Ex: ${}^{32}_{15}P \rightarrow {}^{32}_{16}S + \beta^-$ + antineutrino
Ex: ${}^{3}_{1}H \rightarrow {}^{3}_{2}He + \beta^-$ + antineutrino
Ex: ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + \beta^-$ + antineutrino

The proton remains in the nucleus while the beta particle is emitted, thus there is no change in the mass number. However, since the number of protons is increased by one, the atomic number (Z) also increases by one. During this process, an *antineutrino* particle, having negligible mass and no electrical charge, is also emitted. Beta particles have a range of a few millimeters in tissue, so external exposure does not penetrate to the body core. It can however, produce significant radiation damage to the cells of the skin.

High-energy beta particles can damage the cornea and the lenses of the eyes as well as produce significant skin damage.

5.3.3 Positron Emission

A *positron* (β^+) is a beta particle with a single positive charge ($+1.6 \times 10^{-19}$ C). It has the same rest mass as a negative electron (0.00055 amu) and is emitted from nuclei in which the neutron to proton ratio is very low and α emission is not energetically possible. Positrons and antineutrinos are classified as *antimatter*, whereas negatrons and neutrinos are classified as *matter*.

Positron Decay Formula

${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + \beta^+$ + neutrino

Ex: ${}^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + \beta^+$ + neutrino

During this process, a particle called the neutrino having negligible mass and no electrical charge is also emitted. Whereas negative electrons freely exist, these antimatter positrons have only a transitory existence. The positron rapidly combines with an electron, which results in the annihilation of both particles and the generation of two 511 keV gamma-ray photons. The hazard associated with positron emission results from this gamma radiation.

Gamma (annihilation) radiation requires lead shielding.

5.3.4 Orbital Electron Capture

Electron Capture or "K Capture" is a process whereby one of the K orbit electrons is captured by the nucleus and unites with a proton to form a neutron. An X-ray, characteristic of the daughter element, is emitted when an electron from an outer orbit falls into the energy level occupied by the electron, which had been captured.

Orbital Capture Formula

${}^{A}_{Z}X + e^- \rightarrow {}^{A}_{Z-1}Y + \gamma$ + neutrino

Ex: ${}^{125}_{53}I + e^- \rightarrow {}^{125}_{52}Te + \gamma$ + neutrino

5.3.5 Gamma Rays

Mono-energetic electromagnetic radiations that are emitted from nuclei of excited atoms following radioactive transformations are called *gamma rays* (γ). In most cases, following alpha or beta decay processes, gamma emission is the mechanism by which a nucleus loses energy in going from a high energy excited state to a low energy stable state.

5.3.6 X-Rays

X-rays are electromagnetic radiations generated outside the atomic nucleus. Both X-rays and gamma rays are highly penetrating and can produce whole body radiation doses. One type of X-ray that is a safety hazard in research laboratories is called *bremsstrahlung*. These photons are emitted when electrons are quickly decelerated when interacting with the electric fields surrounding atomic nuclei. The energy of the resultant photon is related to the energy of the incident electron or β^- as well as the electric field strength. These forces are greater in nuclei with a high atomic number. For this reason lead is not an appropriate shielding material for beta isotopes. Using shielding material composed of atoms with low atomic number, such as hydrogen, carbon, and oxygen, the energy and intensity of the bremsstrahlung is minimized. Plexiglas is therefore the shielding of choice.

> *Beta particle interaction with matter results in the production of penetrating bremsstrahlung radiation. Plexiglas shielding is required for beta radiation.*

5.3.7 Other Radiations

Other radiations, such as fast and slow neutrons, mesons, protons, etc. are beyond the scope of this manual, and will not be addressed here.

5.4 Radioactive Decay

5.4.1 Physical half-life ($T_{1/2}$)

Early studies of nuclear substances and radiation devices have shown that the activity of each nuclear substances and radiation devices decreases at its own characteristic rate. For example, when the activity of P-32 is measured daily over a period of two months, and the percentage of the initial activity is plotted as a function of time. Experimental observation shows that one-half of the initial amount of P-32 is gone in 14.3 days, half of that after another 14.3 days, and so on. This period of time in which half of the original activity decays is called the **physical half-life** (PHL).

When as atom decays, the atomic number (Z) is normally altered either by decreasing or increasing the number of protons. Hence, an atom of a specific element rarely decays to the same element, as can be seen in the previous example equations (Isomers are an exception to this rule). This may be of significance in research protocols as the new element may have significantly different chemical characteristics than those of the original.

Given that the half-life of some isotopes is short, it is important to be able to determine the amount of activity that has decayed after purchase but prior to use, over the term of an experiment, as well as the decay period for waste disposal. The precept upon which the calculation of present activity is based is that at some observation time (t), there are a given number of atoms (N). The law of constant fractional decay requires that over a short period of time (dt), the number of atoms decaying (dN), will be

$$dN = -\lambda N dt$$

where the constant of proportionality (λ), is called the decay constant and $N\lambda$ is called the activity (A). Integrating this equation gives the relationship between N and t:

$$N = N_0 e^{-\lambda t}$$ Decay Equation

given that $\lambda = 0.693/T_{1/2}$; then $N = N_0 e^{-0.693\lambda t/T_{1/2}}$

where N is the number of atoms at time t, $T_{1/2}$ is the half-life, and N_0 is the number at t = 0.

Multiplying both sides by λ, and rearranging for $A = N\lambda$:

$$A = A_0 e^{-0.603t/T_{1/2}}$$ Activity Equation

Thus the number of radioactive atoms, and the activity decay away together.

Example: A researcher received a shipment of P-32 labeled 5'-ATP. The supplier documentation indicated that on the shipping date of March 26 the source activity was 555 Mbq. The researcher, however, was unable to use the material until April 30. What was the activity on the day of the experiment?

Data:
$A = ?$
$A_0 = 555$ Mbq
$t = 35$ days
$T_{1/2} = 14.3$ days

$A = 555\ e^{-0.693 \times 35/14.3}$
$A = 101.78$ Mbq

5.4.2 Effective Half-life

The above calculation utilizes the physical half-life of the isotope in question. However, if one is studying a particular process within a living system, such as an animal, plant, or cell line, not only is the physical half-life a determining factor in the clearance of the radio-labeled compound, but the natural secretion and excretion rates of the atoms from the organism also affect the length of time radioactivity is present in the system. The time required for the body to eliminate one-half of an administered dosage of substance by the regular processes of elimination is called the **biological half-life** (BHL). The chemical characteristics of all isotopes of an element are identical; hence the elimination times of both stable and radioactive isotopes of that particular element are the same. The time required for radioactivity to be reduced to fifty percent of the original burden as a result of the combined action of radioactive decay and biological elimination is called the **effective half-life** (EHL). This process is of special importance in the calculation of *in vivo* dosimetry and experimental results of blood volume and tissue isotope concentration studies.

The relationship is: $1/EHL = 1/PHL + 1/BHL$ Half-life Equation

5.5 Units of Radiation

Uranium-238 and a progeny element, thorium-234, each contain about the same number of atoms per gram, approximately 2.5 x 10^{21}. Their half-lives however, are greatly different; uranium-238 has a half-life of 4.5 x 10^{9} years, while thorium-234 has a half-life of 24.1 days. Thorium-234, consequently, is decaying 6.8 x 10^{10} times faster than uranium-238. When nuclear substances and radiation devices are used, the radiations are the center of interest. In this context, 1.5 x 10^{-7} grams of thorium-234 is about equivalent in activity to 1 gram of uranium-238. Obviously, when interest is centered on radioactivity, the gram is not a very useful quantity. The CNSC categorizes Nuclear Substances into classes, based on their radiological characteristics (Appendix III).

Table 1. Half-lives and Radiation Produced by some commonly used nuclear substances and radiation devices

Nuclide	Half-life ($T_{1/2}$)	Emission Energy (MeV)		
		Beta (maximum)	**Positron** (maximum)	**Gamma**
H-3	12.3 years	0.018		
C-14	5,730 years	0.156		
Na-22	2.6 years		1.820	0.511; 1.275
Na-24	14.9 h			
P-32	14.3 days	1.710		
P-33	28.4 days	0.248		
S-35	87.4 days	0.167		
Cl-36	301,000 years			
Ca-45	165 days	0.252		
Cr-51	27.7 days			0.320
Co-57	271 days			0.122
Co-60	5.27 years	1.148; 0.3		1.17; 1.33
Ni-63	100 years	0.067		
Zn-65	244 days		0.327	0.511; 1.116
Cu-67	61.8 days	0.482; 0.576		0.300; 0.393
Rb-86	18.8 days	1.780		1.077
Tc-99m	6 hours			0.141
Ag-110m	249.8 days			0.118
In-111	2.83 days			0.171; 0.245
I-125	60.2 days			0.035
I-131	8.04 days	0.806		0.364; 0.637
Cs-137	30.2 years	1.173		0.662
Ra-226	1,600 years		4.87α	1.186

5.5.1 Units of Activity

Under the International System of Units (SI), the *becquerel* (Bq) is defined as one atomic nuclear transformation per second. Prior to the adoption of the SI units by the scientific community, the Curie was the unit used to quantify radioactivity. Today, most commercial suppliers provide radionuclides in Becquerel and/or curie quantities. Originally the *Curie* (Ci) was defined as the activity of 1g of Ra-226, but was later redefined as the activity of radioactive material in which 3.7×10^{10} atoms disintegrate per second (dps). Consequently, one curie is equal to 2.2×10^{12} disintegrations per minute (dpm).

Sub-multiples of the Becquerel and curie are:

1 becquerel (Bq)	= 1 dps	= 27 pCi
1 kilobecquerel (kBq)	= 1×10^3 dps	= 27 nCi
1 megabecquerel (Mbq)	= 1×10^6 dps	= 27 μCi
1 gigabecquerel (Gbq)	= 1×10^9 dps	= 27 mCi
1 terabecquerel (Tbq)	= 1×10^{12} dps	= 27 Ci
1 millicurie (mCi)	= 2.2×10^9 dpm	= 37 Mbq
1 microcurie (μCi)	= 2.2×10^6 dpm	= 37 kBq
1 nanocurie (nCi)	= 2.2×10^3 dpm	= 37 Bq
1 picocurie (pCi)	= 2.2 dpm	= 37 mBq

5.5.2 Units of Radiation Exposure

The *coulomb/kilogram* (C/Kg) is the SI unit used to measure the radiation-induced ionizations created in a unit mass.

The *roentgen* (R) is the old unit defined as the quantity of radiation that produces ions carrying one statcoulomb of charge of either sign per cubic centimeter of air at 0^oC and 760 mm Hg. One roentgen corresponds to an absorption of 87.7 ergs per gram of air. One C/Kg is approximately equal to 258 microcoulomb/kg (μC/Kg). The *milliroentgen* (mR) is the unit used for the display or readout of most survey meters and portable detection units at the BMSC.

5.5.3 Units of Absorbed Dose

The SI unit used to measure the energy imparted to irradiated matter is called the *gray* (Gy). It is defined as the absorbed radiation dose of one joule per kg. The *RAD* (Radiation Absorbed Dose) is the unit used prior to the establishment of the gray and is defined as an absorbed radiation dose of 100 ergs/g or 0.01 Joules/kg.

1 gray (Gy)	= 1 J/kg
1 gray	= 100 rads

5.5.4 Units of Relative Biological Effectiveness (RBE)

The *Sievert* (Sv) is the SI unit that takes into account the biological effect of the particular radiation emission into the absorbed dose. It is defined as the numerical product of the absorbed dose in grays, multiplied by the appropriate modifying factors. For beta, gamma, and X-rays, this quality factor (QF) equals 1. The quality factor for alpha particles and fast neutrons may be 20 or more. The Sievert replaces the old Roentgen Equivalent Man unit or REM (RAD x QF) where:

1 Sv = 100 rems
1 mSv = 100 mrems
1 μSv = 0.1 mrems

6. RADIATION EXPOSURE AND RISK ASSESSMENT

Since the use of nuclear substances and radiation devices has been permitted by the BMSC Radiation Safety Committee and the Researcher has investigated all other avenues that would allow for the same research to be performed without nuclear substances and radiation devices, they must do everything possible to limit their exposure to ionizing radiation. Despite the adherence to the ALARA principals, all users must monitor the amount of ionizing radiation they are exposed to when performing job related activities. The following are some means of detecting exposures and limits that cannot be exceeded by any person working with nuclear substances and radiation devices.

6.1 Radiation Dosimetry

All users of radiation sources must follow all internal and external dosimetry protocols as set out in the terms and conditions of the license that sanctions their specific research project. The appropriate method of monitoring radiation exposure must be in place before the users will be permitted to work with nuclear substances and radiation devices.

Table 2. Maximum Permissible Doses

Organ or tissue	**BMSC Personnel and General Public** (mSv/y)	**Nuclear Energy Workers** (mSv/y)
Whole body	1	50
Lens of an eye	15	150
Skin*	50	500
Hands and feet	50	500
Abdomen of pregnant woman**	1	4 for the balance of pregnancy

Note: In determining the dose, the contribution from sources of ionizing radiation both inside and outside the body shall be included.

The maximum permissible doses specified in this Table do not apply to ionizing radiation that has been:

a) received by a patient in the course of medical diagnosis or treatment by a qualified medical practitioner; or

b) received by a person carrying out emergency procedures undertaken to avert danger to human life.

* The average equivalent dose to the skin of a person over 1 cm^2 receiving the highest dose.

** See Appendix I - Radiation Exposure Policy for Women at BMSC.

The CNSC set an **annual limit on intake (ALI)** for Nuclear Substances. ALI is the activity (Bq) of a radionuclide that will deliver an effective dose of 20 mSv during the 50 year period, after the radionuclide is taken into the body of a person 18 years or older, or during the period beginning at intake and ending at age 70 after it is taken into the body of a person less than 18 years old ALIs are used to set the certification levels for CNSC regulated laboratories and other facilities (Appendix III).

6.1.1 Personal Monitoring

Thermoluminescent dosimetry, or the newer Optical Stimulated Luminescence technology, are the most accurate methods used to determine personal external radiation exposure. The functional components of a thermoluminescent dosimeter (TLD) are lithium fluoride chips that undergo lattice structure changes when ionized by radiation. This structural alteration "traps" the free electrons in a meta-stable state until the chips are heated, at which point light is emitted. The amount of light produced is proportional to the amount of radiation absorbed, and can be measured and recorded. TLDs are excellent dosimeters for X-rays, gamma radiation and bremsstrahlung from high-energy betas, such as Phosphorus-32, but do not detect radiation from alpha particles or low energy beta particles such as tritium (H-3), carbon-14, or sulfur-35. Functional components of an Optically Stimulated Luminescence Dosimeter (OSLD) are multiple elements which are comprised of crystalline aluminum oxide doped with carbon (Al_2O_3:C) that has been crushed to powder and sandwiched between plastic sheets. Upon exposure to ionizing radiation, these elements passively absorb energy. By placing these elements between shielding filters comprised of different materials (e.g. mylar, heavy plastic, copper or aluminum) within the OSLD, the differential energy absorption of the various elements provide a means by which an exposure can be recorded. During the reading of the OSLD by the dosimetry service, the ratio of energy emitted by the various elements is used to identify the radiation the dosimeter has been exposed to. OSLDs are used for detecting X-rays, gamma and beta radiation.

Any individual working with more than 50 MBq of P-32 is required to wear a wrist or ring dosimeter. This provides an accurate exposure assessment to the fingers and hands. To ensure accurate information is obtained from these devices, it is important that the Mylar coating on the badge holders has no holes or tears, and that exposure to ultraviolet light is minimized during the badge replacement procedure. Most importantly, the badges should always be worn when working with radioactive material and only by the person to whom the badge is issued. Avoid badge contamination and non-personal exposure readings by storing your badge well away from laboratory radiation sources when not in use.

The badges are changed on a quarterly basis and the results are sent to the Radiation Safety Officer for review. All personal exposure data is maintained in the National Dose Registry in Ottawa.

6.1.2 External Exposures

It is possible to calculate the theoretical radiation fields emitted by gamma radiation sources, thus enabling individuals to determine the required shielding and safe working distances for proposed experiments. The calculation is based on the amount of activity, the time spent in

the radiation field, the distance of the individual from the source, and a constant that is a reflection of the emission flux of a given isotope. Table 3 lists the gamma ray constants for some of the isotopes commonly found at Bamfield Marine Sciences Centre.
The theoretical dose to an individual in the vicinity of a point source of radioactivity is defined as:

$$X = \frac{\Gamma A t}{d^2} \qquad \text{Dose Equation}$$

where X = Dose from an external source, Γ = Specific gamma ray constant in (mSv x cm^2)/(h x MBq) at 1 cm, A = Activity of source in Mbq, t = time in hours spent in the vicinity of the source, d = distance from the source in centimeters.

Example: What is the whole body radiation dose a graduate student receives when working with 185 Mbq of Na-22 for two hours every day for 22 days (a working month) at a distance of 35 cm from the source and using no shielding?

Data:
X = ?
t = 44 h
Γ = 3.24 (mSv x cm^2)/(h x MBq)
d = 35 cm
A = 185 MBq

$$X = \frac{3.24 \times 185 \times 44}{35^2}$$

X = 21.53 mSv

Comparing the results with the information in Table 2 we see that this is an unacceptable exposure and shielding will be necessary to perform the experiment safely. Such calculations should be performed before conducting any work with radioactive material to ensure that the prospective work will not be performed in a hazardous environment.

Table 3. Specific Gamma Ray Constants in (mSv x cm2)/(h x Mbq)

Nuclide	Γ	Nuclide	Γ	Nuclide	Γ
Arsenic-74	1.19	Cobalt-58	1.49	Radium-226	2.23
Carbon-14	1.59	Cobalt-60	3.57	Rubidium-86	0.14
Cesium-134	2.35	Cooper-67		Selenium-75	0.54
Cesium-137	0.89	Hafnium-181	0.84	Silver-110m	
Chlorine-36		Iodine-125	0.19	Sodium-22	3.24
Chromium-51	0.04	Iodine-126	0.68	Sodium-24	
Cobalt-56	4.76	Iodine-131	0.59	Tin-113	0.46
Cobalt-57	0.29	Manganese-54	1.27	Zinc-65	0.73

6.1.3 Internal Exposures

Internal dosimetry is more difficult to accurately assess than external doses. In most cases, direct measurements of the amount and distribution of the nuclear substances and radiation devices, are not possible. This is especially true if the isotope ingested is a beta emitter. Calculations of internal doses of beta emitters (H-3, C-14, S-35, Ca-45, and P-32), are based on the amounts of these isotopes that may be found in breath and/or in urine. The nuclear substances and radiation devices iodine-125 and iodine-131 concentrate in the thyroid gland and can be quantified using a calibrated sodium iodide crystal monitor. Due to the need for quarterly thyroid scans when using iodine nuclear substances, they are not permitted for use at the BMSC.

Exposure from other gamma isotopes can be assessed mathematically or with the use of whole body counters. The characteristics of the isotope in question, as well as the proposed experimental protocol, are the determining factors for choosing the appropriate method of monitoring personal radiation exposure.

6.2 Biological Effects of Radiation

Radiation is one of the most thoroughly investigated disease causing agents. Although much still remains to be learned about interactions between living organisms and radiation, more is known about the mechanisms of radiation damage at the molecular, cellular, and organ system levels than is known for most other environmental pathogens.

The accumulation of dose-response data has enabled health physicists to specify environmental radiation levels that allow the use of radiation sources to be conducted at degrees of risk no greater than, and frequently less than, those associated with other technologies.

6.2.1 Acute Effects

Deterministic effects are those for which there exists a clear causal relationship between the amount of exposure and the observed effect. A certain minimum dose must be exceeded before the particular effect is observed, at which point the magnitude or severity of the effect increases with the size of the dose. For example, a person must consume a certain amount of alcohol before behavioural signs of drinking become evident, after which the effect of the alcohol depends on the amount consumed.

Radiation induced deterministic effects can be specific to a particular tissue. About 2 Gy (200 rads) of mixed neutron and gamma radiation or 5 Gy of beta or gamma radiation, will produce cataracts in the lenses of the eyes; cell depletion in bone marrow or hemopoietic syndrome follows a gamma dose of about 2 Gy (100 rads) or greater dose; central nervous system syndrome occurs at a dose of 20 Gy (200 rads). These effects tend to be acute in nature, with the symptoms presenting within days, weeks, or months after exposure. Deterministic effects are also called *threshold effects*, since there is a minimum-dose that must be exceeded before an individual shows signs or symptoms of exposure.

6.2.2 Delayed Effects

Stochastic effects are those for which the dose increases the probability of an effect occurring, rather than its magnitude or severity. Stochastic effects occur by chance and happen among exposed as well as unexposed individuals. When dealing with radiation exposure, the primary stochastic effects are cancer and genetic mutations. Extensive epidemiological studies indicate that these effects occur years after the radiation exposure and have no threshold; that is to say that even at the smallest doses, there is a proportionally small increment in the probability of the effect occurring. Humans develop cancer without having received workplace radiation doses. However, exposure increases the probability of cancer and the greater the exposure, the greater the probability is that the disease will occur. Unlike the causal relationship between alcohol and drunkenness, if an individual does develop cancer, the causal factor cannot be determined. It is, however, possible to estimate the probability that the cancer was caused by radiation induced chromosomal damage.

These delayed effects of radiation may be due either to a single large overexposure or continuing low-level overexposure. Given the nature of the work performed with radiation sources at BMSC, it is most unlikely that any individual could receive a single large dose of radiation that could induce acute deterministic or delayed stochastic effects. The discussion of late effects therefore, will deal with low-level long-term exposure.

Epidemiological data on the carcinogenicity of low doses of radiation are contradictory and inconclusive. Cancer risk estimates are based on exposure histories of the early martyrs, atomic bomb survivors and the large numbers of individuals who have worked, and are working with radiation sources. Simple extrapolation of the risks of radiation exposure from high dose levels does not accurately reflect the incidence of delayed exposure effects. These effects are so very low that it is difficult to separate them from the much greater incidence of stochastic effects that result from other environmental and genetic factors.

The Canadian Cancer Society estimates that about half of all cancers are fatal. Thus, the total incidence estimate of cancer presented in the box below would be doubled to 460-880 cancers per million exposures of 10 mSv. Approximately 25% of all adults will develop cancer induced by environmental and genetic factors not associated with work related radiation sources. Therefore, the increased risk of cancer to an individual occupationally exposed to 10 mSv of radiation would rise from 25% to approximately 25.06%.

Given that the maximum permissible exposure for BMSC workers is 5 mSv per year (women also see Appendix I) and that the average worker exposure is less than 0.1 mSv per year, the risk of suffering long-term radiation effects from occupational exposure is minimal. These estimates are based on current epidemiological evidence and will assist the individual radiation user in making an informed decision concerning acceptance of the risks associated with exposure to radiation. A worker who decides to accept this risk, however minimal, should make every effort to keep their exposure to radiation “As Low As Reasonably Achievable” (ALARA). Users of radiation sources have the primary responsibility for protecting themselves from the associated hazards.

Estimated number of Cancer Deaths due to Exposure to Low Level Radiation: 230-440 Deaths per Million Acute Exposures to 10 mSv U.S. National Academy of Sciences Report on the Biological Effects of Ionizing Radiation (BEIR) 1990

7. RADIATION DETECTION SYSTEMS

7.1 Laboratory Radiation Surveillance

In each area where nuclear substances and radiation devices are utilized, there must be functional monitoring equipment available, capable of detecting the types of radiation in use. All personnel should be familiar with the correct operation of these instruments.

7.1.1 Geiger-Mueller Tube

The most common alpha, beta, and gamma radiation detector is the Geiger-Mueller tube (G-M), and is particularly suitable for radiation protection surveys. A G-M counter is a closed hollow tube containing a gas mixture (He, Ne, or Ar) with the interior under one tenth of an atmosphere of pressure, a thin mica or Mylar membrane (or "window"), a fine wire anode in the center of the barrel insulated from the tube inner wall, and a high voltage potential between the wire and the inner wall of the tube.

An incident particle or photon that ionizes at least one atom of the gas will cause a succession of ionizations in the counter with the resultant electrons captured by the charged center wire. This tremendous multiplication of charge, consisting of perhaps ten billion electrons, will produce, in a typical G-M circuit, a signal of about 1 volt, which is then used to activate a counting circuit. The ionization cascade is stopped or quenched in order that a second event may be detected. A G-M tube requires a certain recovery time after each pulse. If a successive event is initiated by an incident particle before the tube recovers, the discharge will not occur and the event will not be recorded. During the "dead time" the detector is completely unresponsive to additional radiation.

Most beta particles that enter the detector will produce a discharge and register a count on the meter. However, of the gamma or X-ray photons incident upon the counter, only a small fraction will interact and produce ionizations in the chamber. Most of these photons will pass through without any interaction and will not be recorded, thus G-M counters are much more proficient in detecting beta particles than gamma or X-rays. Depending on the energy of the emitted ray, the detection efficiency of a G-M counter is about 1% for X- and gamma rays, but is much higher for alpha and beta particles that enter the counting volume.

Alpha and beta particles can be readily distinguished from photons by the use of absorbers or shields. If a thin absorber or shield (e.g. 1-3 mm aluminum) is placed in front of the window, it will stop the beta particles but will have relatively little effect on the gamma photons. Thus, the counting rate with and without the absorber can be used to distinguish between these two types of radiation. The G-M tube is solely an ionization event counter, and its output signal cannot be used to provide information on the energy or type of the emission nor the identity of the isotope in question.

7.1.2 Solid Scintillation Detectors

Gas-filled G-M tubes do not detect gamma and X-rays efficiently because most of the photons pass through the gas without interaction. The probability of X- and gamma ray detection is increased if a solid detector is used, however, an interaction cannot be registered by collection of electrons and positive ions, as with G-M tubes. Instead, a solid scintillation crystal is utilized to trap the incident radiation, which causes the emission of photons. This light then impinges upon a photosensitive surface in a photomultiplier tube, resulting in the release of electrons. An electrical signal is created, which the circuitry counts as an event.

Among the alkali halide scintillators, thallium-activated sodium iodide crystals, NaI (T1), are the most efficient due to the excellent light yield associated with these materials. The efficiency of a crystal for detecting X-ray and gamma-ray photons increases with the size of the crystal. Detectors using solid crystals can also be used to discriminate the various energy-ranges of X-ray and gamma-ray photons and thus can be used to quantify and identify unknown isotope samples. Sodium iodide crystals degrade from the resultant free iodine release, which in turn decreases the counting efficiency of the system by absorbing much of the radiation-induced fluorescence.

A Low Energy Gamma Scintillator (LEGS) is an example of this detector type and is used primarily to detect contamination with I-125 and other isotopes that emit low energy gamma or soft X-rays. Unlike G-M tubes, LEGS detectors connected to Ludlum survey meters are not calibrated to a standard source and thus any meter reading generated is inaccurate. They are however, extremely useful for quickly identifying gamma isotope contamination sites.

Gamma counters, used mostly in research, also use a solid scintillator. Almost all gamma-emitting isotopes can be counted in this type of instrument.

Most Ludlum Survey Meter-LEGS Detector combinations are not appropriate for quantifying personal exposure fields or waste activity.

7.1.3 Liquid Scintillation Counters

A Liquid Scintillation Counter (LSC) is a very sensitive detection system, widely used in research, which can be used to detect minute quantities of almost any alpha, beta or gamma isotope. An instrument of this type is used for counting labeled experimental samples and wipe tests of potentially contaminated surfaces. The LSC is commonly used to quantify H-3, C-14, P-32, or S-35 samples. Liquid scintillation counting utilizes a scintillating solution (or “cocktail fluor”), which consists of a solvent, a primary chemical fluor and, if necessary, a secondary fluor. The radioactive source or sample is then mixed with the fluor and the resultant photons are collected, multiplied, and counted.

Before performing statistical manipulations on LSC data it is necessary to first convert the counts per unit time (CPM) data to disintegrations per unit time (DPM or Bq). To do this, one must first determine the counting efficiency of the samples. When counting H-3 or C-14, most LSC systems now are able to make that determination. For other isotopes, this conversion requires the creation of standard reference curves.

8. RADIATION SOURCES IN THE WORKPLACE

There are four basic principles that affect the amount of radiation the user will be exposed to when working with radioactive material. They are time, distance, shielding, and contamination control. These are the building blocks of the ALARA principal.

8.1 Time

The radiation dose an individual receives is directly proportional to the length of time spent in a radiation field. Therefore, in order to minimize radiation doses, it is necessary to minimize working times when handling radioactive sources.

Minimize exposure time.

If possible, practice any new protocol or technique with a non-radioactive blank. The importance of this is two-fold. Firstly, you will become aware of any technical difficulties you are likely to encounter and thus avoid handling delays. Secondly, familiarity and practice will reduce the possibility of accidents.

8.2 Distance

It is essential to keep as much distance as possible between a radiation source and the worker. Distance is a very effective factor in reducing the intensity of radiation exposure on the body. The actual relationship follows the inverse square law for point emission sources.

$$\frac{I_1}{I_2} = \frac{(D_2)^2}{(D_1)^2} \qquad \text{Rearranged for } I_2 \qquad I_2 = \frac{I_1 \text{ x } (D_1)^2}{(D_2)^2} \qquad \text{Field Intensity Equation}$$

where I_1 is the intensity of radiation at distance D_1 from the source, and I_2 is the intensity at distance D_2.

Example: The intensity of the radiation at 2 meters from a point source is 13 μSv/h (1.3 mR/h) measured with a G-M detector. What is the radiation field at 50 cm?

Data:

$I_1 = 13$ μSv/h
$D_2 = 200$ cm
$I_2 = ?$
$D_2 = 50$ cm

$$I_2 = \frac{13 \text{ x } 200^2}{50^2}$$

$I_2 = 208$ μSv/h (20.8 mR/h)

The effects of distance on radiation intensity are illustrated below. As the distance from the source gets smaller, the intensity gets progressively larger.

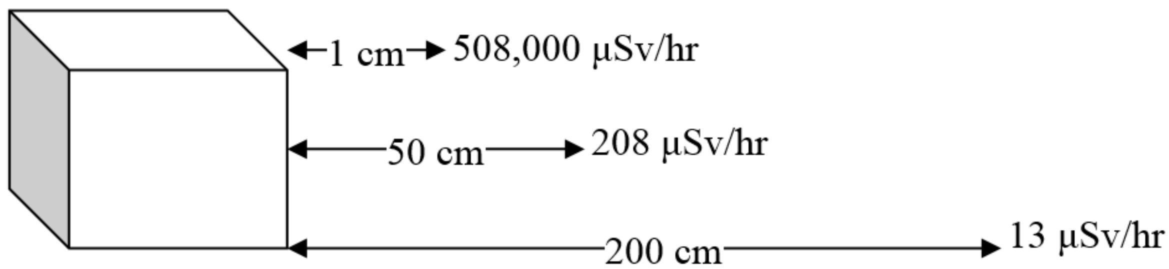

Figure 2. Effect of Distance on Radiation Intensity

8.3 Shielding

The maximum allowable radiation field for any working area is 2.5 µSv/h (0.25 mR/h). In many instances it will not be possible to keep as far from a source as is required, thus necessitating the use of shielding. Depending on the type and energy of radiation, different shielding materials are recommended.

Tritium (H-3) produces very weak beta particles with a maximum energy of 18 keV. These electrons travel only a short distance in matter. The range in air of these particles is about 4.7 mm and a glass stock vial or test tube provides complete shielding.

Carbon-14, sulfur-35, and calcium-45 emit beta radiation with maximum energies of 156, 167 and 252 keV, respectively. If kilobecquerel amounts are handled, the glass container will provide adequate shielding. If tens of megabecquerels are being handled, 3 millimeters thick Plexiglas, lucite, or glass shielding is recommended.

Phosphorus-32 is a high-energy beta emitter (1.71 MeV), consequently most operations require shielding. Thick Plexiglas (1.2 centimeters) is the material of choice. As described in section 3.6, lead is not recommended due to the generation of bremsstrahlung. The energy of these secondary X-rays increases with the increasing atomic number of the target and energy of the beta particle. For this reason, when shielding energetic beta emitters, a material such as plastic or glass is preferred over lead or steel to minimize X-ray exposure.

Phosphorus-33 is a low-energy beta emitter (0.248 MeV). If kilobecquerel amounts are handled, the glass container will provide adequate shielding. If tens of megabecquerels are being handled, 3 millimeters thick Plexiglas, lucite or glass shielding is recommended.

Sodium-22, silver-110m, and cesium-137 emit both beta and gamma radiation, and shielding is always required when these isotopes are used. Good protection is offered by thick lead sheeting, but it is necessary to use a survey meter to check the effectiveness of the shielding (Table 4).

Always use appropriate shielding. Lead is not always the best choice.

Half-Value Layer (HVL) and Tenth Value Layer (TVL)

The thickness of any given absorber that will reduce the intensity of a radiation field to one-half its initial value is defined as a half-value layer (HVL). If the absorber reduces the intensity of the beam to one-tenth it is called a tenth-value layer (TVL). This information is used to calculate theoretical radiation fields.

Table 4. Shielding Materials for Radioactive Sources

Nuclide	Minimum Shielding*
H-3	None required. Stock vial or any container absorbs all radiation.
C-14	None required for activity up to 370 MBq. Then 3 mm Plexiglas.
Na-22	10 cm (4") 2 layers of 2" lead bricks.
Na-24	
P-32	1.2 cm (1/2") Plexiglas.
P-33	None required for activity up to 370 MBq. Then 3 mm Plexiglas.
S-35	None required for activity up to 370 mBq. Then 3 mm Plexiglas.
Cl-36	1.2 cm (1/2") Plexiglas.
Ca-45	None required for activity up to 370 mBq. Then 3 mm Plexiglas.
Cr-51	2.0 cm (3/4") lead.
Co-57	1.7 mm (1/8") lead.
Co-60	10 cm (4") 2 layers of 2" lead bricks.
Ni-63	None required. Electron capture detector housing is adequate.
Zn-65	10 cm (4") 2 layers of 2" lead bricks.
Cu-67	
Rb-86	10 cm (4") 2 layers of 2" lead bricks.
Tc-99^{m}	1.2 cm (1/2") lead.
Ag-110^{m}	10 cm (4") 2 layers of 2" lead bricks.
In-111	2.5 cm (1") lead.
I-125	0.4 mm (1/32") lead.
I-131	6 cm (2 1/2") lead.

* Commercially available shielding material, based on ten half-value layers.

8.4 Contamination Control

Following the use of nuclear substances and radiation devices, it is mandatory to check all work surfaces used during the handling of the nuclear substances and radiation devices for contamination. The methods used to check for radioactive contamination in a laboratory are determined by the physical characteristics of the particular radiation.

During a compliance inspection, a primary role of the CNSC officers is to review the contamination control records. The inspectors also regularly perform their own wipe tests in order to confirm the research laboratory results.

8.5 Wipe test method—Indirect reading method—for non-fixed contamination

Low energy beta particles such as those emitted by tritium, carbon-14, or sulfur-35 do not penetrate the detector window of G-M detectors effectively. These emissions are detected poorly or not at all with a hand-held survey meter. Further, any type of emission (α, β, or γ) resulting from contamination at the stringent level set by the CNSC is not readily detected by a survey meter. For this reason, area wipe tests must be performed when isotopes are actively in use, and at the end of use. When the total concentration of an isotope in use is above its exempted quantity, a wipe test must be completed at minimum once every three days. To perform this test, a disc of filter paper is wetted with ethanol, rubbed over the surface in question (wipe tests are to be conducted over an area of $100cm^2$ (10cm x10cm), or less) and then counted in a liquid scintillation counter. **If the results indicate that the contamination exceeds *100 COUNTS PER MINUTE GREATER THAN BACKGROUND COUNT*, the surface must be decontaminated and re-tested. Records of the numerical results of all wipe tests must be maintained** (Appendix II).

Notes—The BMSC Laboratories Studies Nuclear Substance and Radiation Devices Licence has strict contamination criteria for Class A, B and C Radionuclides. The most stringent of these sets a limit of $3Bq/cm^2$ for non-fixed contamination in permitted locations; maximum levels in all other areas are not to exceed one-tenth of the levels in permitted locations.

Calculating Removable (non-fixed) Activity—Readings from the liquid scintillation counter can be related to regulatory criteria if the efficiency of the instrument for a specific radionuclide is known. For mixtures of radionuclides (radioisotopes), calculations are based on the radionuclide for which the instrument has the lowest efficiency.

Removable Activity = $(N-N_b)/(E*60*A*F)$ Removable activity equation

Where:

N = total count rate in counts per minute (cpm) measured directly or on the wipe
N_b = the count rate of the blank (in cpm)
E = efficiency of the instrument for the radionuclide being measured
(expressed as a decimal (i.e. for 50%, E is 0.5)
60 = seconds/minute
A = area (not to exceed 100 cm^2)
F = collection factor for the wipe. Use a value of F = 0.1 (i.e. 10%)

The 100 cpm greater than background has been established by BMSC (and our member universities) to simplify the wipe test protocol. Justification for this threshold is as follows:

For a wipe test result of 100 cpm above background from a 100 cm^2 wipe test, using E of 0.35 (for tritium; E for other common radionuclides are generally much higher)

100 cpm/0.35 = 285 DPM which is about 5 Bq/ 100 cm^2 or 0.05 Bq/ cm^2.
Assuming that one only collects 10% of the contamination (i.e. F = 0.1), the actual removable activity is 0.5 Bq/cm^2. This exceeds the most stringent regulatory requirement (3 Bq/cm^2) by 6 fold.

In practice, the 100 cpm wipe test criteria gives a good limit that can be universally applied over all operation settings for any isotope on the scintillation counter and is easily remembered by authorized users. This standard is to be applied for non-fixed (i.e. removable) and fixed (i.e. non-removable) sources of radioactivity.

8.6 Direct reading method

To ***supplement*** wipe testing, portable detectors or survey meters may be used to detect high-energy betas, X-rays, and gamma radiation. This is done by holding the detector approximately **TWO CENTIMETERS** above the surface to be monitored. In order to allow sufficient detector response time, it is moved slowly over the area in a grid-like fashion. The instrument should be set on the most sensitive range that is practicable.

While Nuclear Substances and Radiation Devices are being actively used at BMSC, portable G-M Survey Instruments **will** be readily available for use by research and other personnel. These devices must be calibrated on an annual basis and will bear a sticker indicating the date of last calibration.

To operate, follow these general procedures:

- Ensure that clean gloves are worn while handling the instrument to prevent contamination.
- Ensure that the calibration sticker is present and the date is current.
- Test the battery using the "Battery" setting on the rotary dial or the "Battery Test" Button and the rotary dial (depends on the model in use).
- Set the instrument to it most sensitive limit, away from the test location, in an area known to be free of contamination. If the meter registers more than 100 cpm, the probe may be contaminated. Confirm this using another survey instrument or do a wipe test of the probe. Notify the RSO, who will decontaminate the probe.
- Move to the test area. Sweep the probe over the affected area in a grid-like pattern. Go slowly to allow time for the readings to register and ensure that about 2 cm space is left between the surface and the probe. **Touching the probe onto the surface can result in contamination of the probe.**
- Adjust the sensitivity of the instrument as necessary, for the readings to be in scale and record the detected levels.

8.7 Combined method

A combination of the direct reading and wipe test methods provides the best margin of safety. Wipe tests are useful for the detection of loose contamination but will not give any indication of fixed or embedded contamination. The poor counting efficiency of G-M survey meters results in the underestimation of the level of contamination, especially if the levels are low, or if the contaminant is a low energy beta emitter.

> *Wipe tests are mandatory following the use of radioactive material. Decontaminate any surface that exceeds 100 CPM above background. Numerical results must be documented.*

Accidental contamination of work surfaces is a common occurrence in licensed laboratories. It is therefore imperative for the safety of all personnel that wipe tests be performed on a regular basis. It is good practice to also include surfaces and equipment not normally involved in isotope use as part of the laboratory wipe test program.

9. RECORD KEEPING

CNSC Regulations require each licensed research laboratory to maintain complete records of all nuclear substances and radioactive devices for a period ending one year after the expiry of the license. No records will be disposed of without prior authorization from CNSC according to CNSC, GN(28). A comprehensive listing for Record Retention periods is found in Appendix III.

9.1 Purchases

The acquisition of nuclear substances and radiation devices is strictly regulated by laws, which require research scientists to hold a valid CNSC Nuclear Substance and Radiation Devices License or a license from the applicable nuclear regulatory commission of their institution's country prior to obtaining any nuclear substances and radiation devices. An up-to-date record of all purchases, gifts, or donations of nuclear substances and radiation devices must be maintained.

9.2 Usage

It is necessary to record the user's name, date, and activity of each aliquot removed from a stock solution vial. It is advisable to have one "usage sheet" per stock vial that is kept near the isotope storage location.

9.3 Disposals

All waste in the laboratory or decay storage area is part of the permanent nuclear substance inventory. The activity of nuclear substances that are disposed into the solid waste containers, drains, fume hoods, or held for decay must be documented. It is also possible to transfer unused portions of stock material back to the Researcher's home university. A formal request for transfer must be made to the RSO, who will then contact the Researcher's home RSO for the necessary information.

9.4 Contamination Control

CONTAMINATION MONITORING MUST BE PERFORMED WHEN NUCLEAR SUBSTANCES AND RADIATION DEVICES ARE BEING USED. When the total concentration of a nuclear substance in use is above its exempted quantity, a wipe test must be completed at minimum once every three days. The results of these checks, *EVEN WHEN NO CONTAMINATION IS FOUND*, must be recorded and held on file for the license period plus one year. It is advisable to draw a map of the lab and designate areas where monitoring will be performed. Please refer to Sections 8-4 to 8-7 for contamination control procedures.

10. NUCLEAR SUBSTANCES AND RADIATION DEVICES PROCEDURES

The Bamfield Marine Sciences Centre has been issued a Laboratory Studies Nuclear Substance and Radiation Devices License by the Canadian Nuclear Safety Commission, the federal agency responsible for regulating the use of nuclear substances and radiation devices in Canada. Under this license, principal investigators who are licensees of CNSC, are granted authorization that permit nuclear substances and radiation devices to be used for specific purposes in defined locations at BMSC. They and their research personnel must successfully complete a Radiation Safety Course and provide written documentation of completion, prior to the issuing of a permit to use nuclear substances or radiation devices at BMSC. Foreign researchers holding a license from the applicable nuclear regulatory commission of their institution's country may also be permitted to use nuclear substances and radiations devices for specific purposes in defined locations at BMSC, provided they and their research personnel complete the BMSC Radiation Safety Course. Conditions of authorization, Appendix IV, and any amendments to that authorization are in keeping with the legal requirements as defined in the Canadian Nuclear Safety and Control Act. Breeching any of these conditions is a criminal offense. The process for obtaining, modifying, or terminating authorization is detailed in this manual.

10.1 Ordering nuclear substances and radiation devices

Only the Radiation Safety Officer is permitted to order nuclear substances and radiation devices at the Bamfield Marine Sciences Centre. The Researcher may pre-order a nuclear substance using his/her own license and have it transferred/shipped to BMSC prior to his/her arrival. The Nuclear Substance and Radiation Devices License awarded to BMSC clearly indicates which nuclear substances may be used at BMSC and how much nuclear substance may be purchased and stored on hand.

The RSO is responsible for ordering and receiving radioactive substance. Upon receipt of the radioactive substance, the RSO receives the package as described below, and then informs the Researcher of its arrival.

10.2 Receipt of Radioactive Sources (See also Appendix III)

As nuclear substances arrive at BMSC, it is necessary to carefully monitor each shipment. The fiberboard boxes may be contaminated with loose radioactive material on both inside and outside surfaces. The contamination is caused by poor housekeeping at the place of origin, rough handling or leaks developed during transport. It is therefore necessary to establish regular procedures when receiving nuclear substances and radiation devices, using the following guidelines:

- Wear disposable gloves and a lab coat while processing the package;
- Wear eye protection (goggles) if the package contains P-32;
- Verify the labels and transport index (TI);
- Wipe test the exterior for contamination (recommended for UN2910 excepted packages; required for non-excepted packages);
- Remove packaging slip and open outer package;

- Verify that contents agree with packing slip. Check the activity, isotope, and chemical form are what was ordered;
- Measure radiation of inner container and shield as required;
- Check for damage, broken seals, loss of liquid, change in colour, etc;
- Wipe test inner container (recommended for UN2910 excepted packages; required for non-excepted packages);
- Remove or deface the radiation symbol on the shipping label;
- If shipping carton is found to be free of contamination, dispose as regular non-radioactive waste;
- The RSO will complete a Radioactive Material Package Receipt Form (for record purposes) which includes the results of all GM Instrument Surveys and wipe tests, confirmation of identity and additional remarks;
- The RSO will notify the Researcher after all wipe tests have been performed (if applicable) and provide them a copy of the Radioactive Material Package Receipt Form.

10.3 Receipt of damaged packages containing nuclear substances or radiation devices

Given the stringent regulations regarding shipment of nuclear substances and radiation devices (Class 7, Radioactive Materials—under the Transportation of Dangerous Goods Regulations), it is unlikely that a damaged package will be delivered to BMSC. Additionally, BMSC transport personnel are advised not to take receipt of damaged Class 7 packages for transport into Bamfield until the shipper and or consignor can satisfy the RSO that it is safe to do so.

However, in the event that a Class 7 package transported into BMSC is found to be damaged or leaking, the following steps will be taken in addition to the Receipt of Radioactive Sources guidelines

If the package is obviously damaged, but is not visibly leaking, the RSO will:

- Use a G-M Survey Instrument to determine if the package is emitting detectable levels of radiation before moving it to a permitted location. Survey levels are to be recorded on a Radioactive Material Package Receipt Form. If no radiation is detected or the level does not exceed the Transportation Index indicated, the package can be moved to a permitted location for inspection according to the receipt of radioactive sources guidelines.
- If radiation exceeding the Transportation Index is detected, cordon off the area around the package until it can be decontaminated according to BMSC protocols, don appropriate personal protective equipment (before handling the package) and move the package to a permitted location for further inspection.
- Complete external wipe tests and verify that no nuclear material has reached the outer container. If the wipe tests are negative, carefully open the outer container and continue with your visual examination and wipe testing of contents as outlined. If no nuclear material has escaped, process as normal.

- If external tests are negative, but visual inspection or wipe tests confirm that the inner lining has been contaminated, treat the inner container of the package and its contents as radioactive contaminated waste and dispose of according to BMSC protocol. The RSO will report the results of these tests on the Radioactive Material Package Receipt Form.
- **The RSO will immediately advise the CNSC, the shipper and the consignor that the package was received damaged. Note: A follow-up report is to be submitted to the CNSC within 21 days.**
- The RSO will consult with the researcher and reorder as necessary;

- If external tests are positive, the RSO will determine whether to proceed with opening the outer container, based on the identity and activity of the nuclear material. The package will be treated as radioactive contaminated waste and disposed of according to BMSC protocols. Areas that were in contact with the package will be tested and decontaminated according to BMSC protocols; results of contamination wipe tests will be recorded on a BMSC Contamination Control Form and appended to the Radioactive Material Package Receipt Form.
- **The RSO will contact the emergency call number on the TDG shipping declaration or Transport Canada (via CANUTEC 1-613-996-6666), to advise them of the situation. The RSO will immediately advise the CNSC, the shipper and the consignor that the package was received damaged.**
- **Incident reports will be filed with Transport Canada and CNSC. Note: this must be submitted to the CNSC within 21 days.**

If the package is visibly leaking—assume that nuclear substance has escaped

- Cordon off the area around the package until it can be decontaminated according to BMSC protocols.
- Don personal protective equipment before approaching the package. Use a GM Instrument survey to determine if the package is emitting radiation above the indicated Transportation Index. Survey levels are to be recorded on a Radioactive Material Package Receipt Form.
- Place the container into an appropriate container to prevent further spillage and use absorbent material (paper towels, absorbers from a spills kit, etc.) to soak up the liquid. Dispose of the absorbers into the container with the package. Leave the exclusion barriers in place until decontamination of the area has been confirmed.
- Move the container to a permitted location. Complete wipe tests on the exterior surface of the package. If no contamination is found, continue inspection of the package to confirm whether the nuclear substance has escaped, or if the liquid is from another source (e.g. melting refrigerant). Record results of all wipe tests on the Radioactive Material Package Receipt Form.
- If nuclear substance has escaped, treat the container and contents as radioactive waste and dispose of it according to BMSC disposal protocols. Decontaminate all areas in which the package has been located according to BMSC decontamination protocols; results of all wipe tests are to be recorded on a BMSC Contamination Control Form and appended to the Radioactive Material Package Receipt Form.
- **The RSO will contact the emergency call number on the TDG shipping declaration or Transport Canada (via CANUTEC 1-613-996-6666), to advise them of the**

situation. The RSO will immediately advise the CNSC, the shipper and the consignor that the package was received damaged.

- **Incident reports will be filed with Transport Canada and CNSC. Note: this must be submitted to the CNSC within 21 days.**

11. SAFETY IN THE WORKING ENVIRONMENT

11.1 Locations

Nuclear substances and radiation devices may only be used in licensed locations. Busy areas of the workplace should be avoided. When nuclear substances are being used, all personnel in the radiation area must be informed and precautions should be taken to ensure that the maximum allowable working field of 2.5 µSv/h (0.25 mR/h), in any direction from the source, is not exceeded. All access doors to the licensed locations must be clearly signed with the CNSC Basic Level laboratory poster (ISBN: 978-0-662-03915-0, Cat. No.: CC172-127/1-2016E) and a "RAYONNEMENT-DANGER-RADIATION"- with Trefoil Symbol, or similar radiation warning sign. On at least one access door (normally an inner access door) in addition to the Radiation warning sign and CNSC Basic Level Laboratory poster, an abridged copy of the BMSC Laboratory Studies and Radiation Devices License will be posted. Researchers must also post a copy of their BMSC authorization permit (or a copy of the permit from their home institution authorizing work at BMSC), on or beside this door. These permits must identify the Researcher in charge, all authorized personnel and the identity and activity of Nuclear Substances being used, preferably at the most frequently used access door. Permit and CNSC license numbers should appear on these forms. Please refer to section 11-6 additional details.

Note: Per CNSC regulations "Every licensee shall post and keep posted at the boundary and at every point of access to an area, room or enclosure, a durable and legible sign that bears the radiation warning symbol set out in Schedule 3 [trefoil] and the words "RAYONNEMENT-DANGER-RADIATION" if:

a) **There is a radioactive nuclear substance in a quantity greater than 100 times its exemption quantity in the area, room or enclosure; or**
b) **There is a reasonable probability that a person in the area, room or enclosure will be exposed to an effective dose rate greater than 25µSv/h.**

All material used for radioactive work must be labeled with radiation stickers. Warning signs are essential since visitors, cleaning staff, emergency, or maintenance personnel may otherwise be unaware of the presence of the radiation field. Glassware, tongs, and other equipment used to handle unsealed sources should be segregated and labeled to prevent use with non-nuclear materials. Signs and labels should be removed when the equipment has been shown to be free of radioactive contamination and is no longer required for isotope work.

Working surfaces require covering with an absorbent covering to prevent radioactive contamination. Some options are:

1. Absorbent plasticized paper, e.g. Kay-dry, Benchkote, incontinence pads.
2. An absorbent paper-lined tray.
3. A glass plate (for very small volumes only).

Should a spill occur, it can then be easily contained and cleaned up, rather than having to remove and dispose of the contaminated bench.

Refrigerators, freezers and storage cabinets (under the fume hoods, for example) have manufacturer installed locks, or have been retrofitted with locks by BMSC. The BMSC RSO will provide keys and locks to authorized users. When not in frequent use, Nuclear Substances stored in these locations should be locked away. While Nuclear Substances and Radiation Devices are being used in permitted locations, users will ensure that lab entry doors are locked when no researchers are present. When researchers are absent for extended periods from BMSC, exterior doors, lab entry doors and storage locations will be locked and keys will be retained by the RSO.

11.2 Fume Hoods

If there is any possibility of producing airborne radioactivity (aerosols, dust, vapours, etc.), work should be performed in an absorbent paper-lined fume hood. The hood should be labeled with a clearly visible radiation sign. The airflow in each hood is checked by the Research Coordinator on a semi-annual basis; however, should the hood not operate correctly, perform a complete set of wipe tests in the fume hood and remove all hazardous materials. Then forward the results to the RSO (x 255). The RSO will supply a document to be posted that confirms the fume hood is free of radioactive contamination. Maintenance workers will not repair the fume hood without this documented proof.

If there is not an operational magnehelic gauge on the hood, it is good practice to tape a telltale (small piece of tissue paper) to the bottom of the sash to give a visual indicator of airflow.

11.3 Sinks

If possible, only one sink should be used for the washing of contaminated labware and dilution disposal of aqueous radioactive waste. The sink should be clearly and boldly labeled with radiation warning tape or labels that are replaced immediately if they become obscured.

11.4 Refrigerators and Freezers

Store the open source nuclear substances and radiation devices in a refrigerator clearly labeled with a radiation sign. On a routine basis, the refrigerator should be defrosted, cleaned and wipe tested. Ensure that all radioactive samples are labeled with the name of the user, date, isotope, and activity. **Food or beverages *MUST NOT BE STORED* in laboratory refrigerators**.

11.5 Radioactive Sources

In order to minimize degradation of a labeled compound it is often good practice to aliquot the stock solution into smaller volumes, which are then shielded and stored. This lessens the number of freeze-thaw cycles of the stock solutions that can cause degradation of your nuclide labeled chemical compound.

11.6 Posting of Signs and Labels

"RAYONNEMENT-DANGER-RADIATION" with trefoil and "In case of EMERGENCY call ..." labels must be posted at the entrance to each area or laboratory in which radiation hazards may be present as described in 11.1. All storage areas, contamination sites, isotope decay cupboards, etc. must be labeled with a "RAYONNEMENT-DANGER-RADIATION" sign. All licensed rooms must display the "NO EATING OR DRINKING OR SMOKING" and the "RULES FOR WORKING WITH NUCLEAR SUBSTANCES AND RADIATION DEVICESS" signs. These signs and labels may be obtained from the Radiation Safety Officer.

11.7 Miscellaneous

Coat hooks should be provided within the laboratory close to the exit, in order to encourage laboratory personnel to remove lab coats prior to leaving the laboratory. Under no circumstances shall provision be made for food or beverage preparation or storage in the laboratory.

12. PERSONAL PROTECTIVE EQUIPMENT

The primary aim of the Radiation Safety Program is to ensure that nuclear substances and radiation devices are used safely and that radiation exposures are minimized. The individuals using nuclear substances and radiation devices can further this objective simply by ensuring that each and every time they use radiation sources, personal protective equipment is utilized. Apart from radiation hazards, the use of personal protective equipment is further necessitated by the myriad of biological, chemical, physical, and ergonomic hazards present in research areas.

Note—as per Section 2.4 and Section 6.1, authorized investigators will ensure that if required, all personnel using Nuclear Substances and Radiation Devices have been issued, and wear, a thermoluminescent or optically stimulated luminescence dosimeter and participate in bioassay programs as applicable. The BMSC RSO can issue such a device (supplied via Health Canada, National Dosimetry Services) if a user damages or has forgotten their TLD or OSLD. Wrist or Ring dosimeters are mandatory for any person handling a container which contains in excess of 50 MBq of P-32 (or other specific radionuclides; please consult the RSO for a complete list).

12.1 Gloves

The use of disposable gloves is **MANDATORY** when working with open radioactive sources. Gloves should be checked frequently throughout an experiment in order to detect any small punctures that may have developed. Disposable gloves are prone to fail at the fingertips especially if the wearer has long fingernails. Disposable gloves must never be worn outside the laboratory.

12.2 Laboratory coats

Laboratory coats are designed to offer spill protection to the wearer and their use is **MANDATORY** when working with nuclear substances and radiation devices. In order to function properly, the lab coat must be buttoned completely, with the sleeves rolled down fully, thus enabling the wearer to seal the cuffs with gloves. Laboratory coats should not be worn outside the laboratory and may never be worn in areas in which food is consumed.

12.3 Clothing

It is recommended that laboratory personnel wear long pants. These provide splash protection for the lower legs. Jewelry, especially rings, should not be worn in laboratories as contamination is often trapped under the band and may go undetected. If a ring were to be contaminated, it may be impossible to decontaminate and could not be worn again.

12.4 Shoes

Wearing shoes that cover the entire foot is required in all research areas. Sandals, thongs, clogs, etc. do not offer adequate coverage in the event of a spill, nor do they offer protection from falling objects. CSA approved safety shoes are recommended.

12.5 Safety Glasses

A 37 kBq (1 μCi) droplet of phosphorus-32 in the eye will deliver a dose rate of over 20 $mSv/cm^2/h$ (2000 $mrem/cm^2/h$). Safety glasses, goggles, or face guards should be worn when there is a possibility of splashing this material into the eyes. It is also good practice to wear safety glasses as shielding when working with stock solutions of high-energy beta emitters in order to reduce the external radiation dose to the eyes.

12.6 Remote Handling Devices

Forceps and tongs should be used when handling stock solution vials or any source that produces a significant radiation field.

13. MANAGEMENT OF RADIOACTIVE WASTE

13.1 Disposal Procedures

The very nature of scientific research with nuclear substances results in the creation of new and varied forms of radioactive waste. If the type of waste you have generated does not fall within the following classification criteria, or if you have any doubts as to the correct waste stream for a given material, please contact the Head of Research Services/Radiation Safety Officer prior to proceeding with disposal.

The protocol for disposing of radioactive waste at home campus sites may vary from the following BMSC procedures. Ensure that the protocol you intend to follow has been approved by the BMSC Radiation Safety Officer.

Unlike other hazardous substances, nuclear substances and radiation devices are invulnerable to degradation by external chemical and physical processes. Dilution of these atoms into the air, landfills, or bodies of water simply moves them from one location to another. The only mechanism whereby nuclear substances and radiation devices can be eliminated from the environment is by radioactive decay. Therefore, in order to minimize the environmental impact of nuclear substances and radiation devices disposal, it is incumbent upon all users of nuclear substances and radiation devices to strictly follow the guidelines for radioactive waste management.

These guidelines are enforced by law and are administered by the Canadian Nuclear Safety Commission (CNSC) and require detailed accounting of all nuclear substances and radiation devices disposals. Each nuclear substances and radiation devices poses a unique degree of risk to people and the environment. For example, iodine-125 poses a greater potential risk to the thyroid than does ingestion of the equivalent activity of tritium. For this reason the CNSC has set out isotope disposal limits that vary with the associated degree of hazard. These limits are defined as *Exemption Quantities*. A table of Exemption Quantities is found in Appendix III.

All radioactive waste is considered part of the nuclear substances and radiation devices inventory, consequently it is necessary to keep a permanent record (Appendix II) of each occasion when radioactive material is held for decay, diluted to the drains, exhausted from a fume hood, sent for incineration, or sent to a landfill. These records must be complete and a summary of the activity disposed is required to be sent to the RSO on an annual basis. This information is then collated and sent to the CNSC as a condition of the Laboratory Studies Nuclear Substance and Radiation Devices License.

13.1.1 Gases and Aerosols

Procedures for which there is a potential to emit radioactive gases, aerosols, or dusts must be performed in an absorbent paper lined fume hood. The Gas Disposal Limit for radioactive material that may be discharged to the atmosphere is the quantity of nuclear substance per cubic meter of air at the point of discharge, averaged over a one-week period, as stipulated in the Nuclear Substances and Radiation Devices Laboratories Studies Licence. **INTENTIONAL release of radioactive material into the atmosphere is prohibited; these limits are for set for any incidental release, which might occur during the course of an experiment.**

13.1.2 Liquids

Liquid wastes are classified into two groups:

Aqueous - Aqueous liquids should be held in sealed containers until such time as the nuclear substances and radiation devices has decayed. The Nuclear Substances and Radiation Devices Laboratory Studies Licence **prohibits the INTENTIONAL release of any radioactive substance into a municipal sewer**. Incidental release, such as may occur while rinsing glassware, sinks, etc. is permitted, provided activity does not exceed licenced limits. It is essential to continue a good flow of water during these activities to ensure that no radioactive waste remains in the building plumbing.

Organic - All waste organic solvents, including ALL liquid scintillation cocktails (as well as so-called 'Biodegradable cocktail') with or without radioactivity, are to be collected in approved plastic pails. Radiation levels must be recorded on BSMC waste disposal forms and taped to the outside of each pail.

13.1.3 Solids

All solid waste sent for disposal must emit less than 2.5 μSv/h (0.25 mR/h) at the surface of the bag or box. Radioactive waste containers with foot pedal operated lids should be used to minimize contamination of the outer surface and lid. The disposal limits for all solid waste, regardless of type, must be met.

Combustible solids - All combustible waste that contains, or has been contaminated with, nuclear substances and radiation devices is sent to a waste processing facility for incineration. This includes disposable gloves, paper, plastic, bench covering material, plastic test tubes, plastic petri dishes, and plastic tubing. The material should be bagged and boxed or double bagged, with care taken to ensure that the package will not rupture when handled. The isotope disposal sheet should then be placed into the nuclear substances and radiation devices log book.

Exclusive of nuclear substances and radiation devices content, biodegradable material, including biohazards, animals, organs, or parts thereof, must be sent for incineration. If the biohazardous material contains nuclear substances and radiation devices, autoclaving the waste prior to disposal should be avoided, as the process will result in radioactive contamination of the autoclave. In these situations, a waste handling protocol must be approved by the Radiation Safety Officer prior to the commencement of the research.

Non-combustible solids - All low-level radioactive non-combustible waste enters the regular garbage disposal system. It is therefore extremely important that the disposal guidelines of **emission levels of 2.5 μSv/h (0.25 mR/h) or less** is met. Emptied glass scintillation vials and contaminated glassware, pipettes, metal, etc. should all be handled as non-combustible waste. The bag lining the waste container should be sealed and then surveyed with a Geiger-Mueller detector to ensure that the radiation field is less than 2.5 μSv/h (0.25 mR/h). The bag should then be sealed and placed in a GLASS WASTE bucket and disposed via that waste stream. There must be no markings, tape or labeling to indicate that the box may contain very low activity radioactive waste. The container is then disposed of as regular garbage. The isotope disposal sheet should then be placed in your nuclear substances and radiation devices log book. By ensuring the disposal guidelines are met, the radioactivity in the carton does not pose a health hazard to any individual who may be required to handle it.

- *Combustible and non-combustible solid waste emit less than 2.5 μSv/h (0.25 mR/h) at the surface of the disposal container.*

It is essential to ensure that there is full and complete documentation of all quantities of radioactivity disposed as solid waste.

13.1.4 High Activity Waste

Occasions may arise in which the level of radioactive contamination in the waste does not meet the guidelines for nuclear substances and radiation devices disposal. Unlike liquid waste that contains isotopes above the disposal criteria, solid waste may not be diluted to meet the Scheduled Quantity limits. Simply adding a lead brick to a bag of solid waste in order to meet the activity per kilogram disposal criteria does not reduce the concentration or the associated hazard of the radioactive material. In these situations there are two options available.

Decay - When using nuclear substances and radiation devices with half-lives less than 90 days, all solid waste that exceeds the disposal guidelines must be held until the accepted standard is met. It is recommended that holding aqueous liquid waste containing short-lived isotopes for decay is preferable to diluting the waste into the sanitary sewer system.

The BMSC currently uses the Ecophysiology Upper South lab for storage/decay purposes. It is important to label all containers with the initial holding date, the isotope and activity, researcher, user, and anticipated disposal date. As a general rule, ten half-lives will ensure that all isotope has decayed to the acceptable level. Keeping in mind that the radiation fields emitted from these packages may be very high, it is important to print the above information with large bold lettering so that it can be read at a safe distance (Appendix II).

Paint Cans - In situations where the activity to be disposed exceeds the solid waste disposal guidelines, and the half-life of the isotope precludes holding the material for decay, The appropriate containers to be used for this process are new empty paint cans, which are available from most commercial paint stores. Only new empty cans may be used, as the paint from used cans prevents adequate sealing of the lid. BMSC will arrange to transport the waste back to the researcher's home institution (if in Canada), or will contract with a private disposal firm for disposal. Please note that researchers will be charged accordingly for these services.

These containers are appropriate for the disposal of stock solution vials containing unused nuclear substances and radiation devices, columns and heavily contaminated glassware used in iodination procedures, radioactive metals and geological samples, etc. The activity of all isotope waste that is placed in the paint can, must be documented and the disposal records maintained. Arrangements must be made with the Radiation Safety Officer to receive, inspect, catalogue, and ship the sealed paint cans.

Only material that cannot meet the waste limits by any other means may be placed in paint cans for disposal.

14. RADIATION EMERGENCY RESPONSE

14.1 Dealing with Source Incidents and Accidents

Accidents can occur even in the best-run laboratories, and personnel using nuclear substances and radiation devices must be fully conversant with the appropriate procedures to be followed. In order to ensure the appropriate management of any incident of an emergency nature, especially those involving personal contamination, **the Radiation Safety Officer must be notified IMMEDIATELY at ex. 255**. No person shall resume work at the site of an emergency until authorized to do so by the Radiation Safety Officer.

IMMEDIATELY notify the Radiation Safety Officer (ex. 255) in the event of any accidental nuclear substances and radiation devices release, spill of material, or personal contamination.

Section 38 of the Nuclear Substances and Radiation Devices Regulations stipulate the reporting requirements relating to Radiation Emergencies and have informed the policies and procedures described in this section. Major spills must be reported immediately to the CNSC.

An accident is defined as any unintended situation or event that causes injury to personnel or property damage. Incidents are defined as minor occurrences that do not cause injury or damage. The most likely type of radiation incident occurring in a laboratory is a SPILL. The best way to ensure one deals safely with a spill is to prepare in advance. Become familiar with the following procedure and on a regular basis check that the nuclear substances and radiation devices Spills Kit in your lab is well stocked. It should contain the following items:

- disposable latex gloves (or equivalent)
- plastic bags for waste disposal and foot covers
- radiation tape and cleaning rags
- absorbent material (i.e. paper towels)
- decontamination detergent

- gritty cleanser (i.e. Ajax)

Radiation Detection Equipment at BMSC:

At BMSC we have a Perkin Elmer TriCarb Liquid Scintillation Counter (Model # 4910TR; counting efficiency >63% for H-3 and >95% for C-14), which is used to conduct wipe tests.

We also have 3 Ludlum Field Survey Meters (Geiger-Mueller type) to monitor activity levels at a more gross scale, in larger areas. The meters are a Ludlum Model 3: sensitivity 30 mV; Range 0 - 200mR/hr (0 - 2mSv/hr) and two Model 14Cs: sensitivity 40mV; Range 0 - 2000mR/hr (0 – 20mSv/hr). These meters are used to detect broad areas of contamination. They are normally being used to identify “hotspots” requiring cleanup following an experimental usage of nuclear material. In the event of a spill, they are used to quickly assess the gross level of radioactivity in a large area and to determine the extent of spread of contamination from the point of origin. Please refer to Sections 7 and 8 for additional information.

The BMSC Nuclear Materials and Radiation Devices Laboratory Studies License sets limits on allowable levels of radiation in licensed locations (please see Appendix III for classifications) for non-fixed contamination:

3 bq/cm^2 for Class A radionuclides
30 bq/cm^2 for Class B radionuclides
300 bq/cm2 for Class C radionuclides; averaged over an area not exceeding 100 cm^2

Levels in non-licensed areas are not to exceed 1/10 of these levels for each class of radionuclide (i.e. 0.3 bq/cm^2 for Class A radionuclides, 3 bq/cm^2 for Class B radionuclides and 30 bq/cm^2 for Class C radionuclides; averaged over an area of 100 cm^2).

A wipe test reading of 100 counts per minute over background using a 100 cm^2 area, has been established as the threshold above which additional decontamination is required at BMSC. This level exceeds the requirements for Class A radionuclides by 6 fold (Section 8.5). This limit is also to be applied for fixed (i.e. non-removable) contamination.

14.1.1 Spills

The CNSC classifies spill of Nuclear Substances into Minor Spills and Major Spills

Minor Spills—typically involve less than 100 exemption quantities of a nuclear substance

Major Spills —involve more than 100 exemption quantities of a nuclear substance
—involve contamination of personnel
—involve release of volatile material

These must be Immediately Reported to the CNSC

Minor Spills:

A. IMMEDIATELY notify all other people in the vicinity of the spill. Evacuate the area if necessary.

B. If safe to do so, cover the spill with absorbent material to prevent the spread of contamination. Contain the spill and prevent it from spreading.

LIQUID SPILLS: Absorbent material such as paper towels or incontinent pads can be placed directly on the spill. The spill can also be surrounded with an absorbent material such as vermiculate or kitty litter.

POWDER SPILLS: Place dampened absorbent material over spill. Do not use a spray bottle.

C. Turn off any device, instrument, or machine that could enhance the spill.

D. Mark off contaminated area with masking tape, chalk, or rope to restrict traffic.

E. Notify your supervisor and the Radiation Safety Officer (ex. 255) or and inform them of the situation and characteristics of the isotope involved. If levels of radioactivity are very low and no undue hazards exist, cleanup may proceed. However, **if in doubt (due to the material involved or to the extent of the spill), wait for the RSO to arrive**.

F. Remove contaminated clothing and assess if any areas of the body have been contaminated. If the individual is contaminated, follow decontamination procedures listed below.

G. Assess the characteristics of the isotope (type of emission, energy, half-life) and thus determine potential hazards and clean-up procedures.

H. Put on appropriate protective clothing. A minimum of a lab coat, disposable rubber gloves, and close-toed shoes are required. Solvent spills will require the use of a dual cartridge respirator equipped with acid gas/organic vapour cartridges.

I. Use appropriate detector to monitor spill, equipment, and/or people to determine the extent of the spill

J. Clean up the spill using a 2-5% solution of decontamination detergent **taking care not to spread the spill**. Work from the outside towards the centre. If contamination persists, increase the concentration of the detergent. Place contaminated clean-up materials into the Combustible Waste. Wipe test the area carefully to ensure all splatters and spills have been decontaminated.

K. Check hands, clothing and footwear for contamination.

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

Major Spills:

A. Clear the area; all persons not involved with the spill should leave the immediate area. Limit the movement of potentially contaminated personnel until they can be monitored.

B. Leave the fume hood running, to minimize the spread of volatile Nuclear Substances to adjacent areas.

C. Close off and secure the spill area to prevent entry. Post warning signs.

D. Notify your supervisor, the Radiation Safety Officer (ext. 255)

E. The CNSC must be Immediately Notified.

F. The supervisor and/or RSO will direct personnel decontamination and will assess decay and cleanup operations.

G. Follow the procedures for Minor Spills, as appropriate.

H. Record the names of all persons involved in the spill, and record details any personal contamination.

I. An incident report will be submitted to the RSO within 24 hours of the incident.

J. The RSO will file a report with the CNSC.

Note: Per Section 16 of the Radiation Protection Regulations, in the case of an exposure in excess of the applicable radiation dose limits, the RSO will immediately notify the CNSC of the occurrence. Further, the CNSC will be notified of all instances of personnel contamination, through the filing of an incident report.

14.1.2 Sealed Source Leaks

Nuclear substances and radiation devices such as Cs-137 and Ra-226 have to be contained behind shielding at all times. Under some circumstances, sealed sources can leak or be broken. The primary hazard is from external gamma radiation exposure. The CNSC requires leak testing of all sealed sources in excess of 50 MBq at regular intervals, or immediately after an incident that could result in damage to a sealed source. Leak testing involves taking swipe tests of accessible surfaces at or near the sealed source. Readings of 200 Bq or more from the source must be immediately reported to the CNSC and the device taken immediately from service. Appropriate actions must be taken to isolate and safely contain the source and arrange for its disposal. An incident report to the CNSC must be filed within 21 days of an event.

Currently, the BMSC does not have any sealed sources containing 50MBq of activity.

In the event of a sealed source leak

A. Evacuate personnel from the area and post signs.

B. Monitor and cordon-off the "HOT AREA". Some isotopes are not easy to detect and could produce a false sense of security to personnel with little or no experience. Monitoring will require the use of a Geiger-Mueller survey meter and the performance of Swipe tests.

C. Monitor all personnel.
D. Notify Supervisor and Radiation Safety officer (ex. 255). Commence personnel decontamination procedures.

E. Using remote handling devices such as tongs or forceps place the source in a shielded container. The container will be monitored by periodic swipe tests until disposal can be arranged.

F. Using spill cleanup procedures listed above, decontaminate area.

G. The CNSC will be notified immediately of a sealed source leak and an incident report will be filed within 21 days.

14.1.3 Contingency Plan for Failed Decontamination

In the unlikely event that an area still retains a level of activity 100 cpm greater than background after several attempts at decontamination, the following steps will be taken

A. The RSO will cordon off the area around the site and install appropriate shields to contain the radioactivity. If necessary, the entire lab may be sealed and researchers moved to another licenced location.

B. The site will be monitored using the combined method (using survey meter and wipe tests) until levels of radioactivity are reduced to acceptable limits. Frequency of testing is contingent on the identity and activity of the radionuclide.

C. For short half-life radionuclides, the shields will be kept in place and the area monitored periodically until the activity has decayed to safe limits.

D. For long half-life radionuclides, it may necessary to install permanent barriers or shields around the contaminated site, after-which the area must be monitored periodically to ensure the integrity of the containment. In some cases it may be necessary to have the contaminated materials physically removed and disposed of by professional hazardous materials experts; they will ensure that no radiation hazards remain upon completion of their work.

Safety of personnel will be the overriding consideration in determining any response to fixed contamination.

14.2 Decontamination of Personnel

Note: The CNSC considers contamination of personnel as a "Major Spill". The CNSC must be advised immediately, should any personnel, become contaminated by a nuclear substance or radiation device.

The individual involved, or their supervisor, shall ensure that an incident/accident report is submitted to the Radiation Safety Officer, within 24 hours, so that a written report can be submitted to the CNSC within that timeframe.

14.2.1 External Contamination

If an individual has been contaminated with a nuclear substances and radiation devices, the following procedures should be used:

A. Determine the extent of the contamination with the most appropriate sensitive detector.

B. Remove contaminated clothing.

C. Flush the affected areas with copious quantities of lukewarm water for several minutes.

D. Monitor contaminated area. Wash with mild soap. Gently work lather into the contaminated area for 3 minutes. Rinse thoroughly.

DO NOT USE DECONTAMINATION DETERGENTS SUCH AS 'COUNT-OFF', WHICH ARE INTENDED ONLY FOR EQUIPMENT.

E. Monitor, and repeat Step D if contamination persists.

F. Monitor, and if contamination persists, use cold cream or baby oil to clean skin.

G. Monitor, and if contamination persists, DO NOTHING MORE. **DO NOT** use abrasives or caustic detergents. At this point the contamination is bound to the skin and any further manipulation could easily result in injuring or de-fatting the tissue, which would result in internal contamination.

H. Immediately notify the Supervisor and Radiation Safety Officer (ex. 255), who must immediately inform the CNSC of the contamination and file incident reports within 24 hours.

14.2.2 Internal Contamination

If an individual has ingested or has been accidentally injected with a nuclear substance the Radiation Safety Officer must be immediately contacted at ex. 255. If the RSO is unavailable, then the First Aid Attendant or Main Office should be contacted at extension 222 or 221. If an individual has ingested *chemically toxic* radioactive material, treat the chemical toxicity first. Dilution of the stomach contents (conscious victim) by drinking copious amounts of water immediately followed by medical attention is often the best response. Refer to the Material Safety Data Sheet (available from the safety cupboards in each building) for First Aid information. Contact the Poison Control Centre at 723-2135. The CNSC must be informed immediately and incident reports filed within 24 hours of the event.

14.3 Accidents

The injured person or their supervisor shall ensure that an incident/accident report is submitted to the Radiation Safety Officer and First Aid Attendant within 24 hours. If the injured person is a BMSC worker, a WCB Form 7 must be completed by the supervisor and sent to the Worker's Compensation Board within 72 hours of the injury.

14.3.1 Accidents Involving Personal Injury

In the event of personal injury, the treatment of the injury must take precedence, even with contaminated persons. It may however, be possible to "contain" any contamination by confining all such persons to a restricted area.

a) Minor Injuries

1. Treat immediately at or near the scene of the accident.
2. Rinse contaminated wound under a tap with copious amounts of lukewarm water and encourage bleeding.
3. If the wound is on the face, take care not to contaminate the eyes, nostrils or mouth.
4. Wash the wound with mild soap and lukewarm water (see Decontamination procedures).
5. Apply a first aid dressing. The injured areas should be monitored to establish the residual level of radioactivity, if any.
6. Immediately notify the Supervisor and the Radiation Safety Officer (ex. 255).

b) Serious Injuries

1. For situations requiring basic first aid, call the First Aid Attendant. At BMSC, emergencies in which there is serious bodily harm and/or radiation involvement, the Fire Department and Red Cross Outpost should be called by dialing 911. Pull the Fire Alarm if no phone is available. Describe the injuries, the isotope, and amounts involved, as well as physical and chemical form of the material. Have someone meet the emergency team at an agreed-upon entrance to the building in order to lead them quickly to the accident site.
2. Advise emergency personnel of the contamination, nature of injuries, and isotope handling procedures.
3. Ensure that the radioactive material does not further contaminate the accident victim.
4. Isolate contaminated body parts as much as possible using any available shielding material.
5. Immediately notify the Supervisor and the Radiation Safety Officer (ex. 255).

14.4 Nuclear substances and radiation devices (Losses or Thefts)

Losses or theft of radioactive material rarely occurs; however, the Canadian Nuclear Safety Commission treats these situations very seriously and requires immediate reporting of such incidents. Any situation involving the disappearance of radioactive sources **MUST** immediately be reported to the Radiation Safety Officer (ex. 255). Be ready to inform the RSO of the amount, type, and form of the radioactive material that is missing. Please make use of the locks and keys provided to secure your Nuclear Substances, to minimize the possibility of loss or theft. The RCMP will be contacted and details of the theft provided, so that an investigation can be initiated.

14.5 Fire

In the event of a fire in a laboratory involving the use of nuclear substances or radiation devices, pull the fire alarm, shout, "FIRE, FIRE, FIRE, call 911 to report the fire telling emergency services the location of the fire. Contact the Research Coordinator at local 255. Designate people to meet and direct fire fighters to the appropriate location of the fire.

Use a fire extinguisher if the fire is small enough to manage. Make every attempt to avoid fumes from the fire if it involves the immediate area where nuclear substances and radiation devices are being used. If the fire involves the liquid scintillation counter or liquid scintillation fluid, **EVACUATE** the building immediately after closing all doors and windows if it is safe to do so.

If the fire is too large to extinguish, close all doors and windows if it is safe to do so and evacuate the building.

Direct all personnel to collect at a safe point away from the building upwind of any smoke. Be ready to render first aid to any fire burn victims.

Be ready to meet the fire fighters to advise them of the fire involving the presence of nuclear substances and radiation devices.

APPENDIX I: Radiation Exposure Policy for Women at BMSC

The limit set by the Bamfield Marine Sciences Centre's Radiation Safety Committee is that the radiation dose to the abdomen of female workers may not exceed that of the population at large (1 mSv/yr).

Further to this requirement is the policy established by the Canadian Nuclear Safety Commission that following declaration of pregnancy the maximum permissible whole body exposure shall not exceed 4 mSv for the balance of the pregnancy.

The following shall apply:

1. Female personnel working with nuclear substances and radiation devices must **inform in writing** all pregnancies or suspected pregnancies to their home university Department Heads or Supervisors, as well as the RSO and First Aid Attendant at Bamfield Marine Sciences Centre, in confidence, at the earliest possible date.

2. In cooperation with the worker's supervisor, there shall be prompt review of her schedule and work-load to ensure that radiation exposures shall be kept to a minimum.

3. Under certain conditions where it would seem to be prudent to reduce radiation exposures to a substantially lower level and such reductions are not feasible, the worker shall be encouraged to consider termination of any further work within the prescribed radiation area or site.

4. Entry to the prescribed premises shall be denied to persons whose radiation dose approaches the imposed limits.

5. Except where item 4 applies, it shall be the free choice of the pregnant worker to determine whether she shall continue to work with nuclear substances and radiation devices after she has been made fully aware of the risks involved. If she elects to continue working in a radiation environment, she shall be obliged to acknowledge statements by signing the requisite form.

6. The BMSC Radiation Safety Committee shall review all actions taken regarding pregnant workers as provided in the foregoing. This review must include the best interests of the worker and the Centre. Recommendations of the Committee shall be final.

7. All female employees/faculty/students shall be made aware of the above policy prior to the use of nuclear substances and radiation devices or radiation emitting devices.

APPENDIX II: Forms: Nuclear substances and Devices Inventory, Contamination Control, and Waste Decay

The forms on the following three pages contain the information that the Canadian Nuclear Safety Commission requires in order to meet the record keeping regulations. The use of these specific forms is mandatory unless an alternative approved by the BMSC RSO is utilized.

Open Source Inventory Sheet

Location	Radioactive Source	Shipment
Permit Holder:___________________________ Building:________________________________ Lab and Rm.:____________________________ Place of Storage:________________________	Vial ID:________________________________ Isotope:________________________________ Chemical Formula:____________________ Activity:_______________________________ Volume:________________________________	Date Received:________________________ Checked by:___________________________ Wipe Test Results:_____________________ PO#:________________________________ Supplier:_________________________________

Usage Date	User	Activity Used*	Activity Remaining*	Volume Used	Volume Remaining	Disposal of Activity*			
						Aqueous	Solvent	Solid	Decay

Date Vial Finished:	Fate of Stock Vial: Disposal or Held for decay.	Wipe Tests **MUST** correspond to Usage Records

* - Units of activity must be recorded as kBq, MBq, μCi, or mCi

Contamination Control Form

Location Permit Holder: ________________ Lab and Rm.: _________________	When actively using isotopes with a total concentration above their exempted quantity, wipe tests must be performed **every 3 days at a minimum**. Results must be saved and recorded. Sites must be decontaminated and retested if initial counts are **100 CPM above background**. Attach a diagram of the lab showing all sites tested.

Usage Date	User	Control Counts CPM	Site 1 Location or Number	Site 2 Location or Number	Site 3 Location or Number	Site 4 Location or Number	Site 5 Location or Number	Site 6 Location or Number	Site 7 Location or Number	Site 8 Location or Number

Bamfield Marine Sciences Centre
Radiation Safety Policy and Procedures

Low Activity Waste for Decay
Identification Sheet

Permit Holder:_________________________
User:_______________________________
Container (type and ID#):_______________

Isotope	Half-life	Activity	% of Total Activity

Radiation Field at Surface on Entry Date
____________mR/h or ___________ µSv/h
Entry Date (d/m/y):____________________
Disposal Date (d/m/y):__________________
Method of Disposal:____________________

Western Canadian Universities
Marine Sciences Society

Bamfield Marine Sciences Centre
Radiation Safety Policy and Procedures

Low Activity Waste for Decay
Identification Sheet

Permit Holder:_________________________
User:_______________________________
Container (type and ID#):_______________

Isotope	Half-life	Activity	% of Total Activity

Radiation Field at Surface on Entry Date
____________mR/h or ___________ µSv/h
Entry Date (d/m/y):____________________
Disposal Date (d/m/y):__________________
Method of Disposal:____________________

Western Canadian Universities
Marine Sciences Society

Bamfield Marine Sciences Centre
Radiation Safety Policy and Procedures

Low Activity Waste for Decay
Identification Sheet

Permit Holder:_________________________
User:_______________________________
Container (type and ID#):_______________

Isotope	Half-life	Activity	% of Total Activity

Radiation Field at Surface on Entry Date
____________mR/h or ___________ µSv/h
Entry Date (d/m/y):____________________
Disposal Date (d/m/y):__________________
Method of Disposal:____________________

Western Canadian Universities
Marine Sciences Society

Bamfield Marine Sciences Centre
Radiation Safety Policy and Procedures

Low Activity Waste for Decay
Identification Sheet

Permit Holder:_________________________
User:_______________________________
Container (type and ID#):_______________

Isotope	Half-life	Activity	% of Total Activity

Radiation Field at Surface on Entry Date
____________mR/h or ___________ µSv/h
Entry Date (d/m/y):____________________
Disposal Date (d/m/y):__________________
Method of Disposal:____________________

Western Canadian Universities
Marine Sciences Society

APPENDIX III: Reference Documents

The following (tables and information brochures) are provided as reference documents.

Exemption Quantities

ISOTOPE	Bq	uCi	ISOTOPE	Bq	uCi
Americium 241	1 x 10^{3}	2.7 x 10^{-2}	Dysprosium 159	1 x 10^{6}	2.7 x 10
Americium 243	1 x 10^{3}	2.7 x 10^{-2}	Erbium 169	1 x 10^{6}	2.7 x 10
Antimony 124	1 x 10^{4}	2.7 x 10^{-1}	Erbium 171	1 x 10^{4}	2.7 x 10^{-1}
Antimony 125	1 x 10^{5}	2.7	Fluorine 18	1 x 10^{4}	2.7 x 10^{-1}
Arsenic 73	1 x 10^{5}	2.7	Gadolinium 153	1 x 10^{4}	2.7 x 10^{-1}
Arsenic 74	1 x 10^{4}	2.7 x 10^{-1}	Gallium 67	1 x 10^{6}	2.7 x 10
Arsenic 76	1 x 10^{4}	2.7 x 10^{-1}	Gallium 68	1 x 10^{4}	2.7 x 10^{-1}
Barium 131	1 x 10^{5}	2.7	Germanium 68	1 x 10^{4}	2.7 x 10^{-1}
Barium 133	1 x 10^{5}	2.7	Gold 195	1 x 10^{5}	2.7
Barium 140	1 x 10^{4}	2.7 x 10^{-1}	Gold 198	1 x 10^{4}	2.7 x 10^{-1}
Beryllium 7	1 x 10^{6}	2.7 x 10	Hydrogen 3	1 x 10^{9}	2.7 x 10^{4}
Bismuth 206	1 x 10^{5}	2.7	Indium 111	1 x 10^{5}	2.7
Bismuth 207	1 x 10^{5}	2.7	Indium 113 m	1 x 10^{5}	2.7
Bismuth 210	1 x 10^{4}	2.7 x 10^{-1}	Indium 115	1 x 10^{5}	2.7
Bromine 82	1 x 10^{5}	2.7	Iodine 123	1 x 10^{7}	2.7 x 10^{2}
Cadmium 107	1 x 10^{7}	2.7 x 10^{2}	Iodine 125	1 x 10^{6}	2.7 x 10
Cadmium 109	1 x 10^{6}	2.7 x 10	Iodine 129	1 x 10^{6}	2.7 x 10
Cadmium 113 m	1 x 10^{4}	2.7 x 10^{-1}	Iodine 131	1 x 10^{4}	2.7 x 10^{-1}
Cadmium 115	1 x 10^{4}	2.7 x 10^{-1}	Iridium 192	1 x 10^{4}	2.7 x 10^{-1}
Cadmium 115 m	1 x 10^{4}	2.7 x 10^{-1}	Iron 52	1 x 10^{4}	2.7 x 10^{-1}
Calcium 45	1 x 10^{6}	2.7 x 10	Iron 55	1 x 10^{6}	2.7 x 10
Calcium 47	1 x 10^{4}	2.7 x 10^{-1}	Iron 59	1 x 10^{5}	2.7
Carbon 11	1 x 10^{5}	2.7	Krypton 77	1 x 10^{10}	2.7 x 10^{5}
Carbon 14	1 x 10^{8}	2.7 x 10^{3}	Krypton 85	1 x 10^{11}	2.7 x 10^{6}
Cerium 139	1 x 10^{6}	2.7 x 10	Krypton 87	1 x 10^{10}	2.7 x 10^{5}
Cerium 141	1 x 10^{6}	2.7 x 10	Lead 210	1 x 10^{4}	2.7 x 10^{-1}
Cerium 144	1 x 10^{5}	2.7	Magnesium 28	1 x 10^{4}	2.7 x 10^{-1}
Cesium 134	1 x 10^{5}	2.7	Manganese 52	1 x 10^{5}	2.7
Cesium 134 m	1 x 10^{7}	2.7 x 10^{2}	Manganese 54	1 x 10^{5}	2.7
Cesium 137	1 x 10^{4}	2.7 x 10^{-1}	Mercury 203	1 x 10^{5}	2.7
Chlorine 36	1 x 10^{4}	2.7 x 10^{-1}	Molybdenum 99	1 x 10^{4}	2.7 x 10^{-1}
Chlorine 38	1 x 10^{4}	2.7 x 10^{-1}	Nickel 59	1 x 10^{8}	2.7 x 10^{3}
Chromium 49	1 x 10^{5}	2.7	Nickel 63	1 x 10^{7}	2.7 x 10^{2}
Chromium 51	1 x 10^{6}	2.7 x 10	Nickel 65	1 x 10^{4}	2.7 x 10^{-1}
Cobalt 56	1 x 10^{5}	2.7	Niobium 95	1 x 10^{5}	2.7
Cobalt 57	1 x 10^{5}	2.7	Nitrogen 13	1 x 10^{5}	2.7
Cobalt 58	1 x 10^{5}	2.7	Oxygen 15	1 x 10^{6}	2.7 x 10
Cobalt 58 m	1 x 10^{7}	2.7 x 10^{2}	Phosphorous 32	1 x 10^{4}	2.7 x 10^{-1}
Cobalt 60	1 x 10^{5}	2.7	Phosphorous 33	1 x 10^{6}	2.7 x 10
Copper 60	1 x 10^{5}	2.7	Polonium 210	1 x 10^{4}	2.7 x 10^{-1}
Copper 64	1 x 10^{5}	2.7	Potassium 42	1 x 10^{4}	2.7 x 10^{-1}
Copper 67	1 x 10^{5}	2.7	Promethium 147	1 x 10^{7}	2.7 x 10_{2}

Exemption Quantities Continued

ISOTOPE	Bq	uCi	ISOTOPE	Bq	uCi
Radium 226	1×10^{4}	2.7×10^{-1}	Thallium 201	1×10^{6}	2.7×10
Rubidium 86	1×10^{4}	2.7×10^{-1}	Thallium 204	1×10^{4}	2.7×10^{-1}
Samarium 153	1×10^{4}	2.7×10^{-1}	Thorium 232	1×10^{2}	2.7×10^{-3}
Scandium 46	1×10^{5}	2.7	Tin 113	1×10^{5}	2.7
Scandium 47	1×10^{5}	2.7	Uranium (natural) in dispersable form	1×10^{4}	2.7×10^{-1}
Selenium 75	1×10^{5}	2.7			
Selenium 79	1×10^{7}	2.7×10^{2}	Uranium (natural) in non-dispersable form	1×10^{7}	2.7×10^{2}
Sodium 22	1×10^{4}	2.7×10^{-1}			
Sodium 24	1×10^{4}	2.7×10^{-1}	Xenon 123	1×10^{11}	2.7×10^{6}
Strontium 85	1×10^{5}	2.7	Xenon 129 m	1×10^{11}	2.7×10^{6}
Strontium 87 m	1×10^{5}	2.7	Xenon 133	1×10^{11}	2.7×10^{6}
Strontium 89	1×10^{4}	2.7×10^{-1}	Xenon 135	1×10^{10}	2.7×10^{5}
Strontium 90	1×10^{4}	2.7×10^{-1}	Yttrium 90	1×10^{4}	2.7×10^{-1}
Sulphur 35	1×10^{8}	2.7×10^{3}	Zinc 65	1×10^{6}	2.7×10
Technetium 99	1×10^{6}	2.7×10	Zirconium 95	1×10^{5}	2.7
Technetium 99 m	1×10^{7}	2.7×10^{2}			

"Exemption Quantity (EQ)" means

a) in respect of a radioactive nuclear substance set out in column 1 (ISOTOPE), the corresponding quantity set out in column 2 (Bq) of the schedule;

(b) in respect of a radioactive nuclear substance that is not set out in column 1 of the schedule,

(i) 10 kBq, where the atomic number of the substance is equal to or less than 81,

(ii) 10 kBq, where the atomic number of the substance is greater than 81 and the substance, or its short-lived radioactive progeny, does not emit alpha radiation, and

(iii) 500 Bq, where the atomic number of the substance is greater than 81 and the substance or its short-lived radioactive progeny emits alpha radiation; and

(c) in respect of more than one radioactive nuclear substance, any combined quantity of those substances in which the sum of the quotients obtained by dividing the quantity of each substance by its corresponding exemption quantity, as to in paragraphs (a) and (b), is equal to, or greater than one.

Classes of Nuclear Substances

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

Annual Limits on Intake for Commonly Used Nuclear Substances

ISOTOPE	MBq	uCi	ISOTOPE	MBq	uCi
Antimony-124	8	216	Iodine-123	95	2,565
Bromine-82	37	999	Iodine-125	1	27
Cadmium-109	9	243	Iodine-131	1	27
Calcium-45	20	540	Iron-55	100	2,700
Carbon-14	34	918	Iron-59	10	270
Chromium-51	530	14,310	Phosphorous-32	8	216
Chlorine-36	20	540	Phosphorous-33	80	2,160
Cobalt-56	6	162	Radium-226	0.07	1.89
Cobalt-57	95	2,565	Rubidium-86	8.00	216.00
Cobalt-58	27	729	Sodium-22	6	162
Cobalt-60	6	162	Strontium-85	36	972
Fluorine-18	400	10,800	Sulphur-35	26	702
Gallium-67	100	2,700	Technetium-99m	900	24,300
Hydrogen-3	1,000	27,000	Thallium-201	210	5,670
Indium-111	70	1,890			

"ALI" or "annual limit on intake" means the activity, in becquerels, of a radionuclide that will deliver an effective dose of 20 mSv during the 50-year period after the radionuclide is taken into the body of a person 18 years old or older or during the period beginning at intake and ending at age 70 after it is taken into the body of a person less than 18 years old.

Classification of Laboratories

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

Posting of Signs at Boundaries and Points of Access

Rayonnement
DANGER
Radiation

N.B. - To be used if 100 EQ or more of a radio isotope is used

Environment Health and Safety Office: http://www.mcgill.ca/ehs

Rayonnement
DANGER
Radiation

N.B.: To be used if less than 100 EQ of a radio isotope is used

Environment Health and Safety Office: http://www.mcgill.ca/ehs

Basic Level Use of Unsealed Nuclear Substances

BASIC LEVEL
Use of Unsealed Nuclear Substances

Canada's Nuclear Regulator

This room has been classified as basic level for the use of unsealed nuclear substances in accordance with Canadian Nuclear Safety Commission requirements. Below is a list of safe work practices to be followed when working in this room.

24-hour emergency contact (name and phone number)	Room identification

- Do not eat, drink, store food, or smoke in this room.
- Use protective clothing and equipment when working with nuclear substances.
- Clearly identify work surfaces used for handling nuclear substances.
- Check all packages containing nuclear substances for damage upon receipt.
- Store nuclear substances in a locked room or enclosure when not in use.
- In case of a spill or incident involving a nuclear substance, inform others in the area, follow emergency procedures and notify the radiation safety officer immediately.

Notes

A room is classified as basic level for the use of unsealed nuclear substances where more than one exemption quantity is handled and where the largest quantity (in becquerels) of a nuclear substance handled by any worker does not exceed five times its corresponding annual limit of intake (in becquerels). Contact your radiation safety officer for a list of annual limits of intake.

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

nuclearsafety.gc.ca

Canadian Nuclear Safety Commission   Commission canadienne de sûreté nucléaire

Canada

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Proper Care and use of Personal Dosimeters

Canada's Nuclear Regulator

CNSC CCSN

PROPER CARE AND USE OF PERSONAL DOSIMETERS

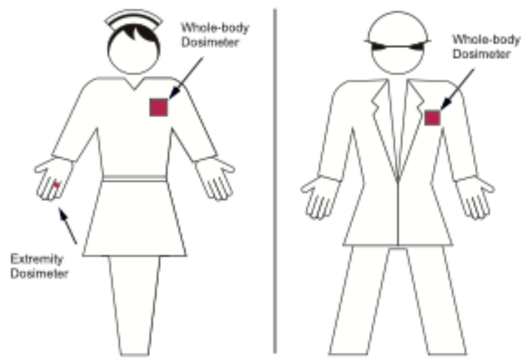
This poster gives useful tips for the proper handling, wearing and storage of whole-body and extremity dosimeters. These are commonly referred to as thermoluminescent dosimeters (TLDs) or optically stimulated luminescent (OSL) dosimeters. Your dosimeter measures the amount of radiation to which you are exposed.

Handling

1. Follow manufacturer recommendations for the care and use of your dosimeter. Do not expose the dosimeter to high temperatures, water, direct sunlight or fluorescent light.
2. Change the dosimeter plaques in a clean, dry area away from direct light, and avoid direct skin contact, if necessary.

Wearing

3. Clip your whole-body dosimeter firmly to your clothing between your waist and neck.
4. Extremity dosimeters should be worn facing the source of radiation.
5. If necessary, wear a second dosimeter on the area of your body most likely to receive the highest dose. In these cases, special arrangements must be made with the dosimetry service provider to ensure doses are assigned properly.
6. If you lose or damage your dosimeter, you should stop working with radiation until you receive a replacement.
7. Do not share your dosimeter.



Storage

8. Store your dosimeter in a manner recommended by the manufacturer when not in use.
9. It is good practice to keep extra dosimeters as replacements for lost or damaged ones and for visitors.
10. When not in use, dosimeters are best stored in a low-radiation background area. Dosimeters should be protected from direct light and heat.

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

nuclearsafety.gc.ca

Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

Canada

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Spill Procedures

Canada's Nuclear Regulator

CNSC CCSN

SPILL PROCEDURES

Name and telephone number of the person responsible for enforcing safe work practices with nuclear substances in this work area:

Radiation safety officer	Telephone number

24-hour emergency contact	Telephone number

General precautions

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

Minor spills (typically less than 100 exemption quantities of a nuclear substance)

1. Wear protective clothing and disposable gloves, clean up the spill using absorbent paper and place it in a plastic bag for transfer to a labelled waste container.
2. Avoid spreading contamination. Work from the outside of the spill towards the centre.
3. Wipe test or survey for residual contamination as appropriate. Repeat decontamination, if necessary, until contamination monitoring results meet the nuclear substances and radiation devices licence criteria.
4. Check hands, clothing, and shoes for contamination.
5. Report the spill and cleanup to the radiation safety officer or the person in charge.
6. Record spill details and contamination monitoring results. Adjust inventory and waste records appropriately.

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

Major spills (Major spills involve more than 100 exemption quantities, or significant contamination of personnel, or release of volatile material)

1. Clear the area. Persons not involved in the spill should leave the immediate area. Limit the movement of all personnel who may be contaminated until they are monitored.
2. If the spill occurs in a laboratory, leave the fume hood running to minimize the release of volatile nuclear substances to adjacent rooms and hallways.
3. Close off and secure the spill area to prevent entry. Post warning sign(s).
4. Notify the radiation safety officer or person in charge immediately.
5. The radiation safety officer or person in charge will direct personnel decontamination and will decide about decay or cleanup operations.
6. Decontaminate personnel by removing contaminated clothing and flushing contaminated skin with lukewarm water and mild soap.
7. Follow the procedures for minor spills or proceed in accordance with authorized procedure.
8. Record the names of all persons involved in the spill. Note the details of any personal contamination.
9. If required, the radiation safety officer or person in charge will arrange for any necessary bioassay measurements.
10. If required, submit a written report to the radiation safety officer or person in charge.
11. The radiation safety officer or person in charge must notify the CNSC immediately and submit a full report within 21 days.

If an exposure may have occurred that is in excess of applicable radiation dose limits, the CNSC shall be notified **immediately** as required by section 16 of the *Radiation Protection Regulations*.

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

nuclearsafety.gc.ca

Canadian Nuclear Safety Commission   Commission canadienne de sûreté nucléaire

Canada

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Guidelines for Handling Packages Containing Nuclear Substances

Canadian Nuclear Safety Commission Commission canadienne de sûreté nucléaire

INFO-0744

GUIDELINES FOR HANDLING PACKAGES CONTAINING NUCLEAR SUBSTANCES

Identifying Packages Containing Nuclear Substances

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

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

Category 1-WHITE
Does not exceed 5 µSv/h at any location on the external surface of the package

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

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

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

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

Opening Packages Containing Nuclear Substances

Radiation Safety Officer	Phone Number

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

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

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

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

Canada

Record Retention Period Summary

The following summarizes the regulatory requirements for retaining records, for licensees who have been issued licences for nuclear substances and radiation devices.

Abbreviations:

GNSC General Nuclear Safety and Control Regulations
RP Radiation Protection Regulations
NSRD Nuclear Substances and Radiation Devices Regulations
PTNS Packaging and Transport of Nuclear Substances Regulations
TDG Transportation of Dangerous Goods Regulations

Record Description	Retention Period	Regulatory Requirement[1]
Licence application and any referenced materials	1 year after the expiry of licence	GNSC 28(1)
Names of authorized users	1 year after the expiry of licence	GNSC 28(1)
Names and job categories of nuclear energy workers (NEWs)	1 year after the expiry of licence	GNSC 28(1)
Location of use	1 year after the expiry of licence	GNSC 28(1)
Storage locations	1 year after the expiry of licence	GNSC 28(1)
Dosimetry results (other than NEWs)	1 year after the expiry of licence	GNSC 28(1)
External dosimetry results for NEWs	1 year after the expiry of licence	GNSC 28(1)
Inventory of nuclear substances and/or radiation devices in possession	1 year after the expiry of licence	GNSC 28(1)
Details of incidents involving nuclear substances	1 year after the expiry of licence	GNSC 28(1)
Purchases and transfers of nuclear substances and/or radiation devices	1 year after the expiry of licence	GNSC 28(1)
List of radiation detection instruments	1 year after the expiry of licence	GNSC 28(1)
Certificate for survey meter calibration	1 year after the expiry of licence	GNSC 28(1)
Decommissioning results for nuclear substances	1 year after the expiry of licence	GNSC 28(1)

[1] As per subsection 28(2) of the *General Nuclear Safety and Control Regulations*, records must be kept until no longer required by the Regulations **and** the Commission must be notified at least 90 days before the intended date of disposal.

Record Description	Retention Period	Regulatory Requirement[1]
Contamination monitoring results when using unsealed nuclear substances	1 year after the expiry of licence	GNSC 28(1)
Records and operating procedures at each site where activities are conducted more than 90 days a year[2]	1 year after the expiry of licence	GNSC 28(1)
Fixed gauges: vessel entry, mounting and dismounting	1 year after the expiry of licence	GNSC 28(1)
Authorizations for sealed source removal	1 year after the expiry of licence	GNSC 28(1)
Pre-operational checks	1 year after the expiry of licence	GNSC 28(1)
Dates and locations of exposure device operation	1 year after the expiry of licence	GNSC 28(1)
Requests for appointments of supervisors and all appointments accepted in response	1 year after the expiry of licence	GNSC 28(1)
Internal audits/inspections for nuclear substances	1 year after the expiry of licence	GNSC 28(1)
Internal audits/inspections and tests for radiation devices	3 years after the expiry of licence	NSRD 36(1)(e)
Training for workers handling nuclear substances (including certificates of training)	3 year after end of employment	NSRD 36(2)
Decommissioning results for radiation devices	3 years after expiry of the licence or revocation, whichever is earlier	NSRD 36(3)
Maintenance and servicing records of radiation devices	3 years after expiry of the licence or revocation, whichever is earlier	NSRD 36(3)
Leak test monitoring results	3 years	NSRD 36(4)
Package documents for shipments using Type IP-2, Type IP-3 or Type A packages	2 years after the date on which the packaging occurred	PTNS 23
Transport documents (for consignee) – Receiver	1 yr after expiry of the licence	GNSC 28(1)
Transport documents (for consignor) – Shipper	2 years after the documents were prepared or given to a carrier	TDG 3.11
TDG training certificate	2 years after expiry of the certificate	TDG 6.6

[2] Records only need to be at the site as long as the site is active; once decommissioned, the records must be maintained at the primary location for 1 year after the expiry of the licence.

APPENDIX IV: Procedures and Forms use nuclear substances and devices

Obtaining authorization

The following material must be submitted to the BMSC RSO when seeking authorization:

1) A completed application form;
2) A copy of the Investigator's full license that has been issued by their institution;
3) A copy of the training certificate of the Investigator and associated lab personnel; and
4) A recommendation letter from their institution's Radiation Safety Officer.

Amending authorization

The Investigator only needs to submit a completed authorization amendment application form to the BMSC RSO. If the Investigator is adding persons to be included for work under their authorization, they must submit a copy of each person's training certificate(s).

De-activating/reactivating Authorization

If an Investigator plans to use nuclear substances and radiation devices for a prolonged period at BMSC rather than specifying a defined period of use, he/she may wish to temporarily (less than 12 months) or permanently deactivate his/her authorization at a later time. If temporarily, reactivation within 12 months from the date of deactivation can be carried out using the deactivating/reactivating form. If Investigators fail to return to BMSC within 12 months from the date of suspension, his/her authorization will be de-activated, and the Investigator must apply for a new authorization.

To deactivate authorization, the Investigator must submit the following:

1) Completion of the authorization deactivate/reactivation form;
2) If deactivating, a complete set of wipe tests for all laboratories authorized for nuclear substance use;
3) If deactivating, a record of proper disposal of nuclear substance(s) on hand. This can include a gift of remaining isotope to another researcher that is licensed for the nuclear substance, or transfer to another license;
4) A complete nuclear substance(s) inventory; and
5) All usage, disposal and contamination control records must be forwarded to the RSO.

Authorization Form to Use Nuclear Substances and Radiation Devices at BMSC

Principal Investigator:___________________________________ Date: _

Institution/Company Affiliation:
Address:
_

_
Phone:________________________ Fax:______________________ Email: _

Authorization for a specified period: From………………………To……………………………
Authorization for a prolonged period: From……………………..To (est)……………………...

Nuclear substances and radiation devices: Please fill out the following table for each isotope you plan to use at BMSC

Isotope	Formula	Total Activity (Bq or Ci)	Provider (Source/University)	Expected Waste Stream (Aqueous, scintillation fluid, solid, transferred)

Proposed use: Please provide a short 2-line summary of the intended use for each isotope

Authorized users: Please list the names of ALL person to be authorized to use nuclear substances and radiation devices under the supervision of the Principal Investigator. **All authorized users are required to have successfully completed a Radioactive Material Handling and Safety Course.**

Name	Position	Date and Place of Training	Certification

Locations: Please list the rooms and areas where radioactive material may be used or stored. Please contact the Research Coordinator/RSO to assist with location allocations.

The Applicant/Principal Investigator accepts full responsibility for all nuclear substances and radiation devices under his/her CNSC license and will ensure that all BMSC conditions, policies, and procedures will be followed. Should the applicant fail to meet the conditions of terminating authorization, the Investigator accepts responsibility for all costs associated with cleaning their authorized work area, at a rate of $300 per diem plus expenses.

____

Signature of Applicant Date (d/m/y)

The material presented in this application is current and accurate to my knowledge. I have attached a recommendation letter for the Principal Investigator under my responsibility.

____

Signature of Home Institution Radiation Safety Officer Date (d/m/y)

Approvals (for Radiation Safety Office use only)

Date of Issue:

____

BSMC Radiation Safety Officer Date (d/m/y)

Authorization status

Activated	Suspended	Re-Activated	Decommissioned	Revoked
Date Date Date				

Amendment Form to Use Nuclear Substances and Radiation Devices at BMSC

Principal Investigator:
Institution/Company Affiliation:
Address:
_

_
Phone:______________________ Fax:_________________________ Email:
_

Authorized users: Please add/remove the following persons to be authorized to use nuclear substances and radiation devices under my supervision. **All authorized users are required to have successfully completed a Radioactive Material Handling and Safety Course.**

Name	Position	Date and Place of Training	Certification

Nuclear substances and radiation devices: Please change the amount/type/nuclide to be permitted under my license.

Isotope	Formula	Total Activity (Bq or Ci)	Provider (Source/University)	Expected Waste Stream (Aqueous, scintillation fluid, solid, transferred)

Proposed use: Please change the intended use of the following isotopes.

The Applicant/Principal Investigator accepts full responsibility for all nuclear substances and radiation devices under his/her CNSC license and will ensure that all BMSC conditions, policies, and procedures will be followed. Should the applicant fail to meet the conditions of terminating authorization, the Investigator accepts responsibility for all costs associated with cleaning his/her authorized work area, at a rate of $300 per diem plus expenses.

____

_ Signature of Applicant	Date (d/m/y)
Approvals (for Radiation Safety Office use only) Date of Amendment: _ ____ _ BSMC Radiation Safety Officer	Date (d/m/y)

Deactivation or reactivation of authorization to use Nuclear Substances and Radiation Devices at BMSC

Principal Investigator:___________________________________ Date: _

Institution/Company Affiliation:
Address:
_

_
Phone:________________________ Fax:______________________ Email: _

Temporary Deactivation of Authorization ☐
Permanent Deactivation of Authorization ☐
Reactivation of Authorization ☐

Nuclear substances and radiation devices: Please fill out the following table for each isotope you used (deactivation) or plan to use (reactivation) at BMSC

Isotope	Formula	Total Activity (Bq or Ci)	Provider (Source/University)	Expected Waste Stream (Aqueous, scintillation fluid, solid, transferred)

Proposed use, if reactivation: Please provide a short 2-line summary of the intended use for each isotope

Authorized users: Please list the names of ALL persons authorized to use nuclear substances and radiation devices (deactivation) or to be authorized (reactivation) under the supervision of the Principal Investigator. **All authorized users are required to have successfully completed a Radioactive Material Handling and Safety Course.**

Name	Position	Date and Place of Training	Certification

Locations: Please list the rooms and areas where nuclear substances and radiation devices were used or stored (deactivation) or the rooms to be used and stored (reactivation). Please contact the Research Coordinator/RSO to assist with location allocations.

The Applicant/Principal Investigator accepts full responsibility for all nuclear substances and radiation devices under his/her CNSC license and will ensure that all BMSC conditions, policies, and procedures will be followed. Should the applicant fail to meet the conditions of terminating authorization, the Investigator accepts responsibility for all costs associated with cleaning his/her authorized work area, at a rate of $300 per diem plus expenses.

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Signature of Applicant Date (d/m/y)

Approvals (for Radiation Safety Office use only)

Date of Issue:

____

BSMC Radiation Safety Officer Date (d/m/y)

Authorization status

Activated	Suspended	Re-Activated	Decommissioned	Revoked
Date Date Date				

GLOSSARY OF TERMS

A: Mass number of a given nuclide.

ABSORPTION: Transfer or deposition of some or all of the energy of radiation traversing matter.

ABSORPTION COEFFICIENT: Since the absorption of gamma or X-rays is exponential in nature, these radiations have no clear cut range. The fractional decrease in the intensity of such a beam per unit thickness of the absorber is expressed by the linear absorption coefficient.

ACCELERATOR (PARTICLE): A device that accelerates charged sub-atomic particles to very great energies. These particles may be used for basic physics research, nuclear substances and radiation devices production or for direct medical irradiation of patients.

ACTIVATION: Absorption, usually of neutrons or charged particles (the minimum energy to induce this effect is 10 MeV) by nuclei thereby making them radioactive.

ACTIVITY: is the number of nuclear transformations occurring in a given quantity of material per unit time. The SI unit for the transformation rate is Becquerel, which is defined as one disintegration per second.

ALPHA PARTICLE (α): A positively charged highly energetic nuclear fragment, comprised of two neutrons and two protons (helium nucleus).

ANNUAL LIMIT ON INTAKE (ALI): The activity, in becquerels, of a radionuclide that will deliver an effective dose of 20 mSv during the 50-year period after the radionuclide is taken into the body of a person 18 years old or older or during the period beginning at intake and ending at age 70 after it is taken into the body of a person less than 18 years old.

ANNIHILATION RADIATION: Positrons interact with negative electrons resulting in the disappearance of both particles and the release of two annihilation 511 keV photons.

ATTENUATION: The reduction of the intensity of a beam of gamma or X-rays as it passes through some material. Beam energy can be lost by deposition (absorption) and/or by deflection (deflection attenuation). The three primary mechanisms by which energy is transferred from the beam to the material through which it passes are the photoelectric effect, the Compton effect and pair production.

BEAM: A flow of electromagnetic or particulate radiation that is generally unidirectional or is divergent from a radioactive source but is confined to a small angle.

BECQUEREL (Bq): The SI unit of activity defined as one nuclear disintegration per second.

BETA PARTICLE (β): Negatively charged particle emitted from the nucleus of an atom. It is just an energetic electron.

BRANCHING: The occurrence of two or more modes by which a radionuclide can undergo radioactive decay to the ultimate stable state. An individual atom of a nuclide exhibiting branching disintegrates by one mode only. The fraction disintegrating by a particular mode is the branching fraction for that mode. The branching ratio is the ratio of two specified branching fractions (also called multiple disintegration).

BREMSSTRAHLUNG: Secondary electromagnetic radiations produced by the rapid deceleration of charged particles in strong electromagnetic fields. The likelihood of emission is proportional to the mass of the nucleus of the absorber.

CARRIER: A quantity of non-radioactive or non-labeled material of the same chemical composition as its corresponding radioactive or labeled counterpart.

CARRIER-FREE: A preparation of nuclear substances and radiation devices to which no carrier has been added and for which precautions have been taken to minimize contamination with other isotopes. Material of high specific activity is often loosely referred to as “carrier-free” but is more correctly defined as “high isotopic abundance”.

COMMITTED DOSE EQUIVALENT: The total dose equivalent averaged throughout a tissue 50 years after body uptake of the radionuclide.

CONTAMINATION, RADIOACTIVE: Unwanted deposition of radioactive material in or on any medium or surface. BMSC policy permits no contamination greater than 100 Counts Per Minute above background.

COULOMB (C): The quantity of electricity transported in one second by a current of one ampere.

COUNTER, SCINTILLATION: Scintillation detection is based on the interaction of radiation with substances known as fluors (solid or liquid) or scintillators. Excitation of the electrons in the fluor leads to subsequent emission of light (scintillation), which is detected by a photomultiplier tube and converted, into an electronic pulse. The pulse magnitude is proportional to the energy lost by the incident radiation in the excitation of the fluor.

CURIE (Ci): The outmoded unit used to quantify activity of radioactive material. Defined as 3.7×10^{10} disintegrations per second.

DECAY CONSTANT: The fraction of atoms undergoing nuclear disintegration per unit time.

DECAY, RADIOACTIVE: Disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.

DOSE EQUIVALENT (H): The product of the absorbed dose, the quality factor (Q) and the product of any other modifying factors (N). For most laboratory purposes N=1.

DOSIMETER, POCKET: A small pocket-sized ionization chamber used for monitoring radiation exposure of personnel.

ELECTROMAGNETIC RADIATION: A spectrum of discrete energy emissions such as radio waves, microwaves, ultraviolet light, visual light, X-rays, gamma rays, etc., having no charge or mass, often called photons or quanta.

ELECTRON CAPTURE: A type of radioactivity in which an atomic electron is absorbed by the nucleus, and is often followed by γ-ray emission.

ENERGY, AVERAGE PER ION PAIR: The average energy expended by a charged particle in a gas per ion pair produced. For most radiological calculations, this value has been normalized to 33.73 eV.

ENERGY, BINDING: The energy represented by the difference in mass between the sum of the component parts and the actual mass of the nucleus.

ENERGY, EXCITATION: The energy required to change a system from its lowest energy state (ground state) to an excited state.

ENERGY FLUENCE: The sum of the energies, exclusive of rest energies, of all particles passing through a unit cross-sectional area.

ENERGY FLUX DENSITY (ENERGY FLUENCE RATE): The sum of the energies, exclusive of rest energies, of all particles passing through a unit cross-sectional area per unit time.

ENERGY LEVELS: Discrete set of quantified energy states within a given atomic nucleus (or atom itself).

ERYTHEMA: An abnormal redness of the skin due to distention of the capillaries with blood. It can be caused by many different agents of which heat, drugs, ultraviolet rays, and ionizing radiation (dose of 10Sv) are the most common.

EXPOSURE (C/kg): A measure of the ionization produced in air by X or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The SI unit of Coulombs per kilogram replaces the outmoded Roentgen unit.

GEIGER-MUELLER TUBE: The major component of laboratory survey meters, which function as incident radiation detectors. A Geiger-Mueller tube is composed of a gas filled hollow tube containing two coaxial electrodes that discharge and recharge following ionizing events.

GENERATOR: Device from which a progeny nuclide is eluted from an ion exchange column containing a parent radionuclide, which is long-lived compared to the progeny.

GENETIC EFFECT OF RADIATION: The radiation induced change in DNA of germ cells resulting in the passing of the altered genetic information to future generations.

GEOMETRY FACTOR: The fraction of the total solid angle about a radiation source that is subtended by the face of the sensitive volume of a detector.

GRAY (Gy): The SI unit of absorbed dose that is equal to one joule per kilogram. Replaces the RAD.

HALF-LIFE, BIOLOGICAL (BHL): The time required for the body to eliminate one half of an administered dosage of any substance by regular process of elimination.

HALF-LIFE, EFFECTIVE (EHL): Time required for a radioactive element in a living organism to be diminished 50% as a result of the combined action of physical half-life (PHL) and biological elimination (BHL).

HALF-LIFE, PHYSICAL (PHL): Time required for a radioactive substance to lose 50% of its activity by decay. Each radionuclide has its own unique half-life.

HALF VALUE LAYER (HVL): The thickness of a specified substance which, when introduced into the path of a given beam of X or gamma radiation, reduces the intensity of the beam by one half.

IONIZATION ENERGY: The energy required to remove one electron from an atom giving rise to an ion pair. In air, the average energy is 33.73 eV.

IRRADIATION: Subjection to radiation.

ISOTOPES: Nuclides with the same atomic number (same chemical element) but different atomic mass numbers.

ISOMER: An excited state of a nucleus that is long-lived. It often de-excites by γ-ray emission, but sometimes by β or α decay.

JOULE (J): The work done when the point of application of a force of one Newton is displaced a distance of one meter in the direction of the force.

LABELLED COMPOUND: A compound consisting, in part, of molecules made up of one or more atoms distinguished by non-natural isotopic composition (either radioactive or stable isotopes). Also see Carrier.

LATENT PERIOD: The period or state of seeming inactivity between the time of exposure of tissue to an injurious agent such as radiation, and the presentation of the associated pathology.

LINEAR ENERGY TRANSFER (LET): The rate at which an incident particle transfers energy as it travels through matter. The unit is keV per micron of path traveled.

LOW ENERGY GAMMA SCINTILLATOR (LEGS): A detection system that utilizes an alkali halide crystal photomultiplier arrangement to detect low energy gamma and x-ray radiation.

MAXIMUM PERMISSIBLE CONCENTRATION (MPC): Limits set on water and air concentration of radionuclides, for 40 or 168 hours per week, which yield maximum permissible body burden values and their corresponding organ dosages.

NON-STOCHASTIC EFFECTS: Induced pathological changes for which the severity of the effect varies with the dose, and for which a threshold must be exceeded, i.e. eye cataracts.

NUCLIDE: A species of atom in which the nuclear constitution is specified by the number of protons (Z), number of neutrons (N) and the energy content; or alternately by the atomic number (Z), mass number (A = N+Z) and atomic mass.

PHOTON: A quantified amount of electromagnetic energy, which at times displays particle characteristics.

POSITRON: A particle equal in mass to an electron and having an equal but positive charge.

POST-CARD: A card (free from RSO) sent to the BMSC Radiation Safety Office upon receipt of radioactive sources purchased on a standing order.

QUALITY FACTOR (Q): The principal dose-modifying factor, which is based on the collision stopping power of an incident particle and is employed to derive the dose equivalent from the absorbed dose.

RADIOACTIVITY: The property of certain unstable nuclides to spontaneously undergo nuclear transformations that result in the emission of ionizing radiations.

NUCLEAR SUBSTANCES AND RADIATION DEVICES: A synonym for radionuclide.

RADIONUCLIDE: A radioactive nuclide.

RADIORESISTANCE: Relative resistance of cells, tissues, organs and organisms to damage induced by radiation.

RADIOSENSITIVITY: Relative susceptibility of cells, tissue, organs and organisms to damage induced by radiation.

RED CAN: Five-litre capacity plastic container used for disposal of organic solvents.

REFERENCE MAN: Compilation of anatomical and physiological information defined in the report of the ICRP Task Group on Reference Man (ICRP Publication 23) that is used for dosimetry calculations.

RELATIVE BIOLOGICAL EFFECT (RBE): A term relating the ability of radiations with different LET ranges to produce a specific biologic response; the comparison of a dose of test radiation to a dose of 250 keV X-ray that produces the same biologic response.

ROENTGEN (R): The outmoded unit of exposure that has been replaced by the SI unit Coulombs per kilogram. One roentgen equals 2.58 x 10^{-4} Coulombs per kilogram of air.

ROENTGEN EQUIVALENT MAN (REM): The outmoded dose equivalent unit that is numerically equal to the absorbed dose in rads multiplied by the quality factor, the distribution factor and any other necessary modifying factor. It has been replaced by the Sievert.
100 rem = 1 Sv.

SCATTERING: Change of direction of subatomic particles or photons as a result of atomic collisions.

SCHEDULED QUANTITY (SQ): A regulated amount of radioactivity of an isotope, the level of which is determined by the relative risk associated with that isotope during shipping or disposal.

SHIELD: Material used to prevent or reduce the passage of ionizing radiation. See also Half Value Layer.

SI (System International): International system of scientific nomenclature.

SIEVERT (Sv): SI unit of dose equivalent that is numerically equal to the absorbed dose in grays, multiplied by the quality factor, the distribution factor and other necessary modifying factors.
1 Sv = 100 rem.

SOMATIC INJURY: Radiation induced damage to cells other than germ cells.

SOURCE TISSUE: Tissue (which may be a body organ) containing a significant amount of a radionuclide following intake of that radionuclide.

SPECIFIC ACTIVITY: Total activity of a given nuclide per gram of a compound, element or radioactive nuclide.

STOCHASTIC EFFECTS: induced pathological changes for which the probability of an effect occurring, rather than the severity, is regarded as a function of dose without threshold (i.e. cancer).

SURVEY METER: A hand held radiation detection instrument. Also see Geiger-Mueller Tube.

TENTH VALUE LAYER (TVL): The thickness of a specified substance which, when introduced into the path of a given beam of X or gamma radiation, reduces the intensity of the beam by a factor of ten.

THERMOLUMINESCENT DOSIMETER (TLD): A small badge worn by workers which is used to passively monitor personal radiation doses. Lithium fluoride crystals are the functional units in the badge in which a small fraction of the energy absorbed from ionizing radiation is stored in a metastable energy state. This energy is later recovered as visible photons, when the material is heated.

TRACER, ISOTOPIC: An isotope or mixture of isotopes of an element or elements which may be incorporated into a sample to permit observation of the course of that element, alone or in combination, through a chemical, biological or physical process. The observation may be made by measurement of radioactivity or of isotopic abundance.

X-RAY: Electromagnetic radiation originating from the orbital electrons of an atom.

Z: Atomic number of a given nuclide.

BMSC Radiation Safety Self-Audit Checklist

Inspected by: Date: Location:

Signs	**Yes**	**No**	**N/A**
Radiation warning signs clearly posted			
Laboratory rules posted			
Emergency contact information posted			
CNSC license posted			
"No eating, drinking…" signs posted			
Work policies and procedures available			
Radiation safety manual available			
Facility	**Yes**	**No**	**N/A**
Laboratory approved for use			
Facility kept clean			
Radioisotope equipment clearly marked			
Survey instrument available			
Fume hood operable			
Radiation levels kept below 2.5 μSv/h			
Contamination levels monitored			
Safety and security procedures in place			
Personnel	**Yes**	**No**	**N/A**
Protective clothing worn			
Personal dosimeters worn			
Personnel authorized to use isotopes			
Personnel trained/certified			
Workers designated as NEW (Nuclear Energy Workers)			
RSO appointed			

Storage/Disposal	Yes	No	N/A
Radioactive material secured			
Storage area locked			
Warning signs posted			
Authorized access only			
Transportation	**Yes**	**No**	**N/A**
CNSC licensed for transport			
Transportation procedures in place			
Approved shipping packages			
Shipping documentation complete			
Proper signs on packages			
Approved mode of transport			
Records	**Yes**	**No**	**N/A**
Record-keeping procedures in place			
Personnel authorization list			
Record of staff training			
Swipe and leak test results			
Nuclear substance inventory			
Transport documents			
Non-conformances			
Disposal of nuclear substances			
Transfer of nuclear substances			
Dosimetry records			
Contamination records			
Incidents			
Records up-to-date			

Comments: