Radiation Safety Training Manual
Contact Information

1. Radiation Incidents
   Radiation Safety Manager       Jill Robertson       (902) 494-1938 (office)
   Environmental Health and Safety Office       (902) 494-2495
   Director of EH&S       Jerry Aguinaga       (902) 494-1241
   Non-Emergency Line       Dalhousie Security       (902) 494-6400

2. Emergency numbers
   EMERGENCIES
   Dalhousie Security       (902) 494-4109
   Dalhousie Health Service       (902) 494-2171
   Poison Control       1-800-565-8161

3. Members of the Radiation Safety Committee
   James Fawcett         Chair
   Jill Robertson       RSM
   Jerry Aguinaga       Director EHS
   Rachel Thompson       Biosafety and Radiation Safety Technician
   Paul Bourgeois       Tupper Building Manager
   Neale Ridgway         Pediatrics, Biochemistry & Molecular Biology
   Nichole McMullin       Microbiology & Immunology
   Dasse Nadaradjian     Biochemistry (DMNB)
   Sarah Roberts        Technician (IWK)
   Stephanie Kienast       Oceanography
### Table of Contents

**Section 1 - Introduction**
- Canadian Regulations .................................................................................................................. 5
- What You Need to Know About Radiation .................................................................................. 6
- Radiation and the World We Live In ......................................................................................... 7

**Section 2 – Properties of Radiation**
- Radiation and Radioactivity ...................................................................................................... 11
- The Atom ................................................................................................................................ 12
- Alpha Particle Radiation ............................................................................................................ 13
- Beta Particle Radiation .............................................................................................................. 14
- Gamma Radiation ...................................................................................................................... 15
- X-Ray Production (Bremsstrahlung) .......................................................................................... 16
- Penetrating Distances .............................................................................................................. 17
- Half-life ................................................................................................................................... 18
- Gas Filled Detectors ................................................................................................................ 19
- Scintillation Detectors ............................................................................................................. 20

**Section 3 – Biological Effects**
- Biological Effects of Radiation .................................................................................................. 21

**Section 4 – Basic Radiation Protection**
- What are the Hazards Associated with Ionizing Radiation ..................................................... 26
- The Workplace ........................................................................................................................... 26
- Careful Planning ....................................................................................................................... 28
- Safe Work Habits ...................................................................................................................... 28
- Control of Radioactive Contamination ..................................................................................... 29
- Video Activity ........................................................................................................................... 30

**Section 5 – Key to Contamination Detection and Control**
- Contamination Control ............................................................................................................ 42
- Direct Monitoring for Contamination ....................................................................................... 43

**Section 6 – Radioactive Decontamination Procedure**
- Decontamination Principles ...................................................................................................... 45
- Spill Clean Up Procedure ......................................................................................................... 47
- Decontamination of Personnel and Equipment ........................................................................ 49
- Radiation Incident Report ......................................................................................................... 50
- Radioactive Spill Contamination/Clean Up Survey ................................................................. 52

**Section 7 – Radiation Safety Policies**
- ALARA Statement .................................................................................................................... 53
- ALARA Policy ............................................................................................................................ 54
- Classification of Radiation Workers .......................................................................................... 60
- Prenatal Exposure Policy .......................................................................................................... 64
- Radiation Safety Training Policy ............................................................................................... 68
- Ascertaining and Recording Doses ............................................................................................ 70
- Thyroid Monitoring, Screening, and Bioassay Policy ............................................................... 73
- Sealed Source Leak Testing Policy ............................................................................................ 75
- Security of Nuclear Substances ................................................................................................. 78
- Transfer of Nuclear Substances and Radiation Devices .......................................................... 81
- Packaging and Transport of Nuclear Substances and Radiation Devices ............................. 85
- Receiving of Nuclear Substances ............................................................................................... 88
- Controlling Possession of Nuclear Substances ......................................................................... 91
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchasing Policy</td>
<td>93</td>
</tr>
<tr>
<td>Radiation Emergency Procedures Policy</td>
<td>95</td>
</tr>
<tr>
<td>Decommissioning – Renovations, Remodels, Moves, Terminations</td>
<td>100</td>
</tr>
<tr>
<td>CNSC Reporting Requirements</td>
<td>105</td>
</tr>
<tr>
<td>Record Keeping Requirements</td>
<td>108</td>
</tr>
<tr>
<td>Laboratory Classifications</td>
<td>112</td>
</tr>
<tr>
<td>Animal Care Policy</td>
<td>114</td>
</tr>
<tr>
<td>Internal Review and Enforcement Policy</td>
<td>117</td>
</tr>
<tr>
<td>Internal Authorization Permits</td>
<td>120</td>
</tr>
<tr>
<td><strong>Section 8 – Radiation Safety Policies</strong></td>
<td>124</td>
</tr>
<tr>
<td>Nuclear Substances</td>
<td>124</td>
</tr>
<tr>
<td>Unsealed Nuclear Substances</td>
<td>125</td>
</tr>
<tr>
<td>Sealed Sources</td>
<td>127</td>
</tr>
<tr>
<td>Nuclear Substance Disposal</td>
<td>128</td>
</tr>
<tr>
<td>Exposure to Personnel</td>
<td>129</td>
</tr>
<tr>
<td>Radiation Warning Signs and Notices</td>
<td>130</td>
</tr>
<tr>
<td>Nuclear Substances in Teaching Programs</td>
<td>132</td>
</tr>
<tr>
<td><strong>Section 9 – Emergencies</strong></td>
<td>134</td>
</tr>
<tr>
<td>Radioactive Contamination</td>
<td>134</td>
</tr>
<tr>
<td>Accidents</td>
<td>135</td>
</tr>
<tr>
<td>Fire</td>
<td>136</td>
</tr>
<tr>
<td><strong>Section 10 – Appendicies</strong></td>
<td>137</td>
</tr>
<tr>
<td>Teaching Lab Enrollment Form</td>
<td>137</td>
</tr>
<tr>
<td>Safe Handling of Nuclear Substances</td>
<td>138</td>
</tr>
<tr>
<td>Nuclear Substance Data Sheets</td>
<td>140</td>
</tr>
<tr>
<td>Glossary of Terms</td>
<td>149</td>
</tr>
<tr>
<td>Chronology of Radiation Protection</td>
<td>154</td>
</tr>
<tr>
<td>References</td>
<td>156</td>
</tr>
</tbody>
</table>
Section 1 - Introduction

CANADAN REGULATIONS
PURSUANT TO THE SAFE USE OF NUCLEAR SUBSTANCES

Introduction:

The Atomic Energy Control Act, adopted in 1946, governed Canada’s approach to regulating nuclear energy and materials for the last half of the 20th century. While regulatory practices have evolved to keep pace with industry and to increase focus on health, safety, security and environmental protection, the legislation itself had not changed. New legislation was required to provide a more modern and effective regulatory framework.

The Nuclear Safety and Control Act was passed by Parliament in 1997 to better reflect the current regulatory mandate and priorities. The legislation replaced the outdated Atomic Energy Control Act and paved the way for the creation of the Canadian Nuclear Safety Commission (CNSC). The strengthened regulations and new authorities given to the Commission represent the first major overhaul of Canada’s nuclear regulatory regime since the creation of the Atomic Energy Control Board (AECB) more than 50 years ago.

Before the Act could come into force, it was necessary to modernize the regulations that govern nuclear energy and materials to incorporate common licence conditions and reflect current legal, financial, and technical standards. Following an extensive consultative process and the drafting of new regulations, the Nuclear Safety and Control Act came into force on May 31, 2000, enabling the formal launch of the CNSC.

The Canadian Nuclear Safety Commission regulates the use of nuclear energy and materials to protect health, safety, security and the environment and to respect Canada’s international commitments on the peaceful use of nuclear energy. Under the Nuclear Safety and Control Act, the Commission’s objectives are to:

- Prevent unreasonable risk to the environment or to the health and safety of the public
- Prevent unreasonable risk to national security
- Achieve compliance with international treaties and obligations on the peaceful use of nuclear energy
- Provide objective scientific, technical and regulatory information to the public concerning the Commission’s activities and the effects on health, safety and the environment of the nuclear industry

Like its predecessor, the AECB, the CNSC will regulate activities involving nuclear energy or materials in Canada, from nuclear power plants and nuclear research facilities, to equipment for diagnosis and cancer treatment, the operation of uranium mines, the use of radioactive sources for oil exploration, to radioisotopes used in various industries. The Commission will also continue to play an active role in helping Canada meet its international commitments with respect to nuclear non-proliferation, safeguards and security.

The Commission has considerable new compliance and enforcement powers which will enable it to regulate more effectively.
WHAT YOU NEED TO KNOW ABOUT RADIATION

Introduction:

The problem today, for many people is that the word RADIATION conjures up visions of atomic bombs, nuclear power plant accidents, nuclear wastes, or radioactive fallout; it summons up the fear of cancer. When asked about their source of information about radiation, most people cite newspapers, television, movies, or just casual gossip. Media rarely try to educate with facts; they tend to emphasize the dangerous and sensational to appeal to emotions. People tend to base their opinions about radiation on well publicized accidents such as Three Mile Island, Chernobyl and Japan.

Uncontrolled use of ionizing radiation can be hazardous, but so can uncontrolled use of almost anything, including salt and pepper. There is no such thing as absolute safety in any human activity.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Est. Life Expectancy Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health</td>
<td></td>
</tr>
<tr>
<td>Smoking (20 cigs/day)</td>
<td>6 years</td>
</tr>
<tr>
<td>Overweight (15%)</td>
<td>2 years</td>
</tr>
<tr>
<td>Alcohol (Canadian average)</td>
<td>1 year</td>
</tr>
<tr>
<td>All accidents</td>
<td>207 days</td>
</tr>
<tr>
<td>All natural hazards</td>
<td>7 days</td>
</tr>
<tr>
<td>Occupational Exposure (&lt;3 mSv/yr)</td>
<td>15 days</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
</tr>
<tr>
<td>All industries</td>
<td>60 days</td>
</tr>
<tr>
<td>Agriculture</td>
<td>320 days</td>
</tr>
<tr>
<td>Construction</td>
<td>227 days</td>
</tr>
<tr>
<td>Mining</td>
<td>167 days</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>40 days</td>
</tr>
</tbody>
</table>

Another way of looking at risk is to look at the relative risk of a 1 in a million chance of dying of activities common to our society:

- Smoking 1.4 cigarettes (lung cancer)
- Eating 40 tablespoons of peanut butter
- Spending 2 days in New York (air pollution)
- Driving 40 miles by car (accident)
- Flying 2500 miles by jet (accident)
- Canoeing for 6 minutes
- Receiving 0.1 mSv of radiation exposure (cancer)
What is Radiation?

Simply put radiation is energy in the form of waves.

To illustrate: What do you do when you see a calm pond of water, perhaps with some wood chips or leaves floating on the surface? From the point where the rock hits the water, ripples radiate in rings. These ripples (waves) are a form of radiation. The ripples represent the movement of some energy imparted by the rock when it hit the water. As each ripple reaches a wood chip, they rise to the crest of the wave. The lifting of the wood chip shows that the waves have energy and that some energy has been moved from the spot where the rock hit the water to the place where the wood chip was lifted. The general idea is the same for other types of radiation.

There is one particular characteristic of all radiation that helps to identify and describe it. That is wavelength, the distance from the crest of one wave to the crest of the next wave.

Waves in water are one form of radiation. There is another class, that we call electromagnetic radiation. This is the type if radiation that Dalhousie University’s Radiation Safety program is concerned with.

Types of Radiations:

<table>
<thead>
<tr>
<th>Non-Ionizing Electromagnetic</th>
<th>Ionizing Electromagnetic</th>
<th>Ionizing Atomic Particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio Waves</td>
<td>X-Rays</td>
<td>Alpha Particles (α)</td>
</tr>
<tr>
<td>Microwaves</td>
<td>Gamma Rays</td>
<td>Beta Particles (β)</td>
</tr>
<tr>
<td>Infrared (heat)</td>
<td>Cosmic Rays</td>
<td>Neutrons</td>
</tr>
<tr>
<td>Visible light (color)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultra-violet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Where Does Radiation Come From?

Natural Radioactivity:

*Cosmic radiation* comes through the earth’s atmosphere, some from the sun and energy sources inside or outside our galaxy. Those from the sun are more intense during solar flares. The density is affected by the earth’s magnetic field, which makes it greater nearer the poles and the equator. Cosmic radiation dose increases with latitude. The earth’s atmosphere is a partial shield to the radiation. As one goes higher there is a lower shielding effect, thus, radiation dose increases.

*The earth’s crust* is made up of materials that are naturally radioactive. Uranium is dispersed throughout rocks and soil, as are thorium and potassium 40. They all emit gamma rays which irradiate the whole body uniformly. Since building materials are extracted from the earth, they are slightly radioactive.

*Radon* is a naturally occurring radioactive gas that comes from the uranium in the earth’s crust. It is emitted from rocks or soil at the earth’s surface and disperses in the atmosphere unless it enters a building where the concentration may build up.

*Food and drink* - Since radioactive materials occur everywhere in nature it is inevitable that they make their way into drinking water and food. Potassium 40 in particular is a major source of internal irradiation.

Artificial Radiation:

*Radiation in the work place* - Persons in many occupations encounter above background levels above normal background as part of their job. Some of these occupations include doctors, nurses, technologists, astronauts, dental hygienists, pharmacists, welders and flight crews. It is interesting to note that flight crews receive higher occupational radiation exposure than does the average research worker in a university.

*Medical uses of radiation* are roughly broken down into diagnostic and therapeutic. Therapy is primarily used for tumor killing of cancer, but in the past has been used for other treatments. Most of the dose is received in a small area of the body. Diagnosis runs from routine x-rays and blood tests to injections of radioactive material for imaging. The physician who prescribes radiation treatment must weigh the risk of the radiation exposure with the benefit of the treatment.

*Radioactive fall-out* from nuclear weapons testing carried out in the atmosphere is the most widespread environmental contaminant but doses to the public have declined from the relatively high values of the early 1960’s to very low levels now.
The nuclear power industry releases small amounts of a wide variety of radioactive materials at each stage in the nuclear fuel cycle.

Non-nuclear industries, including the processing of ores containing radioactive materials as well as the element for which the ore is processed (phosphorus ores contain radium), and the generation of electricity by coal-fired power stations, results in the release of naturally occurring radioactive material from the coal.

Radiation in consumer products - Minute radiation doses are received from the radioactivity in consumer goods such as in smoke detectors and luminous watches, and from the natural radioactivity in cigarettes and gas mantles.

Examples of natural and man made sources of radiation exposure:

- A 150 pound person contains 150 grams of potassium 42, mostly in muscle.
- Tobacco smokers and many Inuit whose diets consist largely of reindeer meat (reindeer feed on lichens) are exposed to levels of lead 210 and polonium 210.
- The dose at the top of Mt. Everest is about 20 millisievert/year.
- Beaches in Brazil which are composed of monazite sand emits up to 175 millisievert/year.
- In Morro do Ferro, Brazil where there is a rich deposit of thorium, plants growing there have absorbed so much radiation that they can produce X-ray photographs of themselves.
- Phosphate fertilizers have a concentration of uranium and thorium. Potassium fertilizers add approximately 111 terabecquerel (Tbq) to United States farmlands each year.
- In 1977 there were an estimated 8.4 million radium timepieces in use in the United States, delivering a collective dose of 2500 person-rems/year.
- Uranium ores are used in some ceramic glazes to produce a shiny orange or yellow color in crockery and decorative glassware.
- About 10% of the enamel used in enameled jewellery contains uranium or thorium.
- Uranium is used to give porcelain false teeth the brightness of natural teeth.
- Thorium and uranium are often present in the silica and other natural materials from which lenses are made.
- Camping lanterns use thorium to improve the quality of the light they emit.
- Hospitals, clinical laboratories and physicians need no licence to buy some radioimmunoassay kits in the United States. Industry sources estimate that a million or more of these kits are sold annually in the U.S.
What are the Risks of Radiation Exposure?

*Radiation is all around us.* Humans have been exposed to radiation from natural sources since the dawn of time. We have discussed this in the previous section under natural radioactivity. *This radiation cannot be avoided.* For those workers who must be occupationally exposed to radiation, we strive to maintain their exposures “ALARA” (*as low as reasonably achievable*). Occupationally exposed workers receive no benefit from their exposure. Patients undergoing x-ray or Nuclear Medicine procedures to diagnose disease or broken bones, however, do derive a benefit from their risk taken in being exposed. Personnel exposure limits are reported in millisievert (mSv) units. The *Canadian Nuclear Safety Commission* requires that radiation exposure to “*A person who is not a Nuclear Energy Worker (NEW)*” (which includes all occupationally exposed workers at Dalhousie) does not exceed 1 millisievert per year. The average dose to an occupationally exposed worker at Dalhousie does not exceed 0.5 millisievert per year.

Radiation causes ionizations in the molecules of living cells. These ionizations result in the removal of electrons from the atoms, forming ions or charged atoms. The ions formed then go on to react with the other atoms in the cell, causing damage. An example of this would be if a gamma ray passes through a cell, the water molecules of DNA might be ionized and the ions might react with the DNA causing a break.

At low doses, such as what we receive from background radiation, the cells repair the damage rapidly. At higher doses (1 Sv), the cells might not be able to repair the damage, and the cells may either be changed permanently or die. Most cells that die are of little consequence; the body replaces them.
Section 2 - Properties of Radiation

Radiation and Radioactivity

- Radiation: Energy in transit, either as particles or electromagnetic waves
- Radioactivity: The characteristic of various materials to emit ionizing radiation
- Ionization: The removal of electrons from an atom. The essential characteristic of high energy radiations when interacting with matter.

Radiation is energy traveling in the form of particles or waves in bundles of energy called photons. Some everyday examples are microwaves used to cook food, radio waves for television, light, and x-rays used in medicine.

Radioactivity is a natural and spontaneous process by which the unstable atoms of an element emit or radiate excess energy in the form of particles and waves. These emissions are collectively called ionizing radiations. Depending on how the nucleus loses this energy either a lower energy atom of the same form will result, or a completely different nucleus and atom can be formed.

Ionization is a particular characteristic of the radiation produced when radioactive elements decay. These radiations are of such high energy that when they interact with materials, they can remove electrons from the atoms in the material. This effect is the reason why ionizing radiation is hazardous to health, and provides the means by which radiation can be detected.
A typical model of the atom is called the Bohr Model, in honor of Niels Bohr who proposed the structure in 1913. The Bohr atom consists of a central nucleus composed of neutrons and protons, which is surrounded by electrons which orbit around the nucleus.

Protons carry a positive charge of one and have a mass of about 1 atomic mass unit (amu). Neutrons are electrically neutral and also have a mass of about 1 amu. In contrast electrons carry a negative charge and have a mass of only 0.00055 amu. The number of protons in a nucleus determines the element of the atom. For example, the number of protons in uranium is 92 and the number in neon is 10. The proton number is often referred to as $Z$.

Atoms with different numbers of protons are called elements, and are arranged in the periodic table with an increasing $Z$.

Atoms in nature are electrically neutral so the number of electrons orbiting the nucleus equals the number of protons in the nucleus.

Neutrons make up the remaining mass of the nucleus and provide a means to “glue” the protons in place. Without neutrons, the nucleus would split apart because the positive protons would repel each other. Elements can have nuclei with different numbers of neutrons in them. For example hydrogen, which normally only has one proton in the nucleus, can have a neutron added to its nucleus to form deuterium, or have two neutrons added to create tritium, which is radioactive. Atoms of the same element which vary in neutron number are called isotopes.
Alpha decay is a radioactive process in which a particle with two neutrons and two protons is ejected from the nucleus of a radioactive atom. The particle is identical to the nucleus of a helium atom.

Alpha decay only occurs in very heavy elements such as uranium, thorium and radium. The nuclei of these atoms are very neutron rich (i.e. have a lot more neutrons in their nucleus than they do protons). Thus, when uranium-238 (which has a Z of 92) decays by alpha emission, thorium-234 is created (which has a Z of 90).

Because alpha particles contain two protons, they have a positive charge of two. Further, alpha particles are very heavy and very energetic compared to other common types of radiation. These characteristics allow alpha particles to interact readily with materials they encounter, including air, causing much ionization in a very short distance. Typical alpha particles will travel no more than a few centimetres in air and are stopped by a sheet of paper.
Beta decay is a radioactive process in which an electron is emitted from the nucleus of a radioactive atom, along with an unusual particle called an antineutrino. The neutrino is an almost massless particle that carries away some of the energy from the decay process. Because this electron is from the nucleus of the atom, it is called a beta particle to distinguish it from the electrons which orbit the atom.

Like alpha decay, beta decay occurs in isotopes which are neutron rich. Atoms which undergo beta decay are located below the line of stable elements on the chart of nuclides, and are typically produced in nuclear reactors. When a nucleus ejects a beta particle, one of the neutrons in the nucleus is transformed into a proton. Since the number of protons in the nucleus has changed, a new daughter is formed which has one less neutron but one more proton than the parent. For example rhenium-187 (Z=75) decays by beta decay, osmium-187 (Z=76) is created. Beta particles have a single negative charge and weigh only a fraction of a neutron or proton. As a result, beta particles interact less readily with material than alpha particles. Depending on the beta particle energy, beta particles will travel up to several metres in air, and are stopped by thin layers of metal or plastic.
After a decay reaction, the nucleus is often in an excited state. This means that the decay has resulted in producing a nucleus which still has excess energy to get rid of. Rather than emitting another beta or alpha particle, this energy is lost emitting a pulse of electromagnetic radiation called a gamma ray. The gamma ray is identical in nature to light or microwaves, but of very high energy.

Like all forms of electromagnetic radiation, the gamma ray has no mass and no charge. Gamma rays interact with material by colliding with the electrons in the shells of atoms. They lose their energy slowly in material, being able to travel significant distances before stopping. Depending on their initial energy, gamma rays can travel from 1 to hundreds of metres in air and can easily go right through people.

It is important to note that most alpha and beta emitters also emit gamma rays as part of their decay process. However, there is no such thing as a pure gamma emitter. Important gamma emitters, including technetium-99m which is used in Nuclear Medicine and cesium-137 which is used for calibration of nuclear instruments.
Over a century ago, in 1895, Roentgen discovered the first example of ionizing radiation, x-rays. The key to Roentgen’s discovery was a device called a Crookes tube, which was a glass envelope under high vacuum, with a wire element at one end forming the cathode, and a heavy copper target at the other end forming the anode. When a high voltage was applied to the electrodes, electrons formed at the cathode would be pulled towards the anode and strike the copper at very high energy. Roentgen discovered that very penetrating radiations were produced from the anode, which he called x-rays.

X-ray production occurs whenever electrons of high energy strike a heavy metal target, like tungsten or copper. When electrons hit this material, some of the electrons will approach the nucleus of the metal atoms where they are deflected because of their opposite charges (electrons are negative and the nucleus is positive). This deflection causes the energy of the electron to decrease, and this decrease in energy then results in forming an x-ray.

Medical x-ray machines in hospitals use the same principle as the Crookes tube to produce x-rays. The most common x-ray machines use tungsten as their cathode, and have very precise electronics so that the amount and energy of the x-ray produced is optimum for making images of bones and tissues in the body.
The most common types of radiation include alpha particles (α) beta (β) and positron particles, gamma (γ) and x-rays and neutrons. Alpha particles are heavy and doubly charged which cause them to lose their energy very quickly in matter. They can be shielded by a sheet of paper or the surface layer of your skin. Alpha particles are only considered hazardous to a person’s health if an alpha emitting particle is inhaled or ingested. Beta and positron particles are much smaller and only have one charge, which cause them to interact more slowly with material. They are effectively shielded by thin layers of metal or plastic and are again only considered hazardous if a beta emitter is ingested or inhaled (P-32 excepted).

Gamma emitters are associated with alpha, beta and positron decay. X-rays are produced either when electrons change orbits within an atom, or electrons from an external source are deflected around the nucleus of an atom. Both are forms of high electromagnetic radiation which interact lightly with matter. X-rays and gamma rays are best shielded by thick layers of lead or other dense material and are hazardous to people when they are external to the body.

Neutrons are neutral particles with approximately the same mass as a proton.
Radioactive half-life ($T^{1/2}$) is the time required for the quantity of radioactive material to be reduced to one half its original values.

All radioisotopes have a unique half-life, some of which are very long ($^{14}$C = 5730 years), while others are very short ($^{99m}$Tc = 6 hours).
The most common type of instrument is a gas filled radiation detector. This instrument works on the principle that as radiation passes through air or a specific gas, ionization of the molecules in air occurs. When a high voltage is placed between two areas of the gas filled space, the positive ions will be attracted to the negative side of the detector (cathode) and the free electrons will travel to the positive side (anode). These charges are collected by the anode which then forms a very small current in the wires going to the detector. By placing a very sensitive current in the wires from the cathode and anode, the small current measured and displayed as a signal. The more radiation which enters the chamber, the more current displayed by the instrument.

Many types of gas filled detectors exist, but the two most common are the ion chamber used for measuring large amounts of radiation and the Geiger-Mueller or GM detector used to measure very small amounts of radiation.
The second most common type of radiation detection instrument is the scintillation detector. The basic principle behind this instrument is the use of a special material which glows or scintillates when radiation interacts with it. The most common type of material is a type of salt called sodium iodide (NaI). The light produced from the scintillation process is reflected through a clear window where it interacts with a device called a photomultiplier tube.

The first part of the tube is made of another material called a photocathode. The photocathode has the unique characteristic of producing electrons when light strikes the surface. These electrons are then pulled towards a series of plates called dynodes through the application of a positive high voltage. When electrons from the photocathode hit the first dynode, several electrons are produced for each initial electron hitting its surface. This "bunch" of electrons is then towards the next dynode, where more electron multiplication occurs. The sequence continues until the last dynode is reached, where the electron pulse is now millions of times larger than it were at the beginning of the tube. At this point the electrons are collected by an anode at the end of the tube forming an electronic pulse. The pulse is then detected and displayed by a special instrument.

Scintillation detectors are very sensitive radiation instruments and are used for special environmental surveys and as laboratory instruments.
Section 3 - Biological Effects of Radiation

How Radiation Affects Biological Organisms

Radiation induced injuries begin with molecular damage. Charged particles (such as α and γ particles) transfer their energy via ionization and excitation interactions. Massless and chargeless gamma or x-rays must first interact with some atom in the cell. In these processes the gamma or x-ray transfer energy to an electron which then causes ionizations and excitations within the materials surrounding them.

Since most of the human body is comprised of water, a majority of these interactions will occur in water molecules. The splitting apart, or radiolysis, of water is brought about by the transfer of energy from alphas, betas, or electrons to the water molecule.

Free radicals are neutral atoms or molecules with unpaired electrons. They are extremely reactive. If several solutes are available the free radical will react with molecules of the largest size, number, and chemical reactivity, in that order.

Direct hits on solute molecules most likely occur, but this is a very small portion versus the indirect effects from free radicals. Large molecules in biological systems are often sensitive to radiation induced structural changes; these include degradation and intermolecular and intramolecular cross linking. The presence of oxygen during irradiation enhances the chemical and biological effects by increasing the number of harmful radicals and or by blocking the repair of damaged molecules.

The multi-target, multi-hit theory describes the phenomenon of more complex biological systems that are irradiated. This theory state that many targets exist which requires multiple hits before an effect is realized. Cell death thus depends on factors such as the type of cell and the linear energy transfer (LET) of the particular radiation. LET is the rate that energy is imparted to a medium over a specified distance. A high LET radiation, such as an α particle, may deposit enough hits to a cell while the number of hits to deeper cells would be very limited. On the other hand, a low LET γ emitter might only cause one hit over many cells but effect cells that are far deeper into the tissue.

In 1906, two French radiobiologists, (Bergonie & Tribondeau) recognized that different types of cells differ in their radiosensitivity. They stated cells have increased radiosensitivity if:

- Their mitotic rate is high
- They have a long mitotic future
- They are of a primitive cell type (not specialized)

The ability of a cell to repair damage done by a given amount of absorbed radiation can be highly variable and dependent on many factors. Some of these are:

- Cellular repair capability
- Linear energy transfer (LET) for the particular radiation
- Synergistic effects from other metabolic processes
- Delivery rate of the dose

The three dimensional structure of a cell membrane can be altered. For example, a nerve cell may lose the ability to conduct electrical impulses.
The damage produced by low doses of radiation can be repaired by cells. This is demonstrated by dividing a dose into two or more fractions and noting that the cellular mortality is less for the single dose of the same total amount. Experiments show the cells receiving fractionated doses have higher survival rates, with repairs starting immediately after irradiation.

The radiosensitivity of tissues within an organism under the action of ionizing radiation is also highly variable. Tissue radiosensitivity in mammals, from the most radiosensitive to the least is as follows:

1) Embryonic tissue
2) Hematopoietic organs
3) Gonads
4) Epidermis
5) Intestinal mucous membrane
6) Connective tissue
7) Muscle tissue
8) Nervous tissue

Categorizing Effects

It is known that high levels of exposure can cause biological effects that are harmful to the exposed organisms. These effects are classified into three categories:

1) **Somatic effects**: effects occurring in the exposed individual that may be divided into two classes.
   a) Prompt effects - observable soon after a large dose, >1 Sv to the whole body
   b) Delayed effects - may occur years after an exposure
2) **Genetic effects**: abnormalities passed on to future generations as a result of a parent's exposure
3) **Teratogenic effects**: effects that may be observed in children who were exposed during fetal and embryonic stages of development. These can be in the form of deterministic or stochastic effects.

Additionally, effects are also referred to as deterministic (non-stochastic) and stochastic. Deterministic effects are those in which the severity of the effect increases with dose above an apparent threshold. Some examples of deterministic effects are erythema and cataracts. Stochastic effects are those in which the probability of an effect, rather than its severity, is assumed to increase linearly with a linear increase in dose. An example of stochastic effects would be cancer induction.
Radiation Syndromes in Adults from Whole Body Exposures

Acute radiation syndrome takes place within 30 days following a high dose of radiation received to the whole body. The LD 50 (30) value is used for expressing lethality dose to 50% of the exposed organisms.

There are four recognized radiation syndromes which are named by the clinical symptoms that arise from each range of acute radiation dose.

1) **Molecular Death Syndrome** - results from doses of 1000 Gy or more. Death is immediate, associated with the inactivation of critical molecules (DNA, RNA).

2) **Central Nervous System Syndrome** - results from doses of 100 to 1000 Gy. Death occurs one or two days after exposure, associated with incoordination, respiratory failure, and intermittent stupor.

3) **Gastrointestinal Syndrome** - results from doses of 9 to 100 Gy. Death occurs from 3-5 days after exposure, associated with morphological changes in the GI tract.

4) **Hematopoietic Syndrome** - results from doses between 3 to 9 Gy. If death occurs, it is generally 10-15 days after exposure, resulting from changes in the blood cells.

Whole body doses of >50 mGy or more produces symptoms of radiation sickness. The symptoms include:

- Headache
- Dizziness
- Nausea
- Diarrhea
- Insomnia
- Decrease in white blood cells & platelets

Treatment is generally given after clinical conditions exist; such as, large doses of antibiotics, after an infection is contracted.

**Non-Lethal Deleterious Effects of Radiation**

Other effects that are often a concern to individual workers, and their threshold ranges are listed below.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Threshold Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hair loss (epilation)</td>
<td>5 Gy (temporary loss) 25 Gy (permanent loss)</td>
</tr>
<tr>
<td>Reduced sterility</td>
<td>Female - (2 Gy to the ovaries) Male - (0.5 Gy to the testis)</td>
</tr>
<tr>
<td>Permanent sterility (&amp; &amp; %)</td>
<td>8 Gy (acute) 15 Gy (fractionated)</td>
</tr>
<tr>
<td>Cataracts</td>
<td>2 Gy (acute) 14 Gy (fractionated) to lens of eye</td>
</tr>
</tbody>
</table>
Potential Benefits of Radiation Exposure

There are obvious benefits from exposure to radiation such as in medical treatment and diagnostic procedures that far outweigh any potential health risks. A very controversial topic in the field of Health Physics is whether low level doses of radiation may also have a therapeutic effect. The concept is known as hormesis and is very similar to the theory employed in many modern day health practices. Vitamins and minerals that would be lethal at high levels exhibit a beneficial effect if taken in moderation. Current work on radon exposures by Dr. Bernard Cohen at the University of Pittsburgh seem to indicate that the observed effects are opposite of what is predicted. People living in the higher radon level environments demonstrate a lower incidence of lung cancer and live longer.

Cancer Risk Estimates

How radiation causes cancer is not well understood and it is impossible to tell whether a given cancer was caused by radiation or some other cause. General physical condition, inherited traits, age, sex, and exposure to other cancer causing agents can all be contributing factors. One hypothesis is that radiation can damage chromosomes in a cell which can cause an abnormal growth. Another is that radiation reduces the body=s normal resistance to existing viruses which can multiply and damage cells. A third is that radiation activates an existing virus or proto-oncogene in the body which can then initiate cancerous growths.

The American Cancer Society has estimated that approximately 25% of all adults will develop cancer sometime from all possible causes such as:

- Smoking
- Food contaminants
- Alcohol
- Drugs
- Air pollutants
- Natural background radiation

Thus, in any group of 10,000 workers not exposed to radiation on the job, about 2500 cases of cancer can be expected to develop. If this entire group of 10,000 workers were to receive an occupational radiation dose of 10 mSv each, an additional three cancer cases can be expected.

Radiation Effects on Prenatal Development

Low level dose effects are not statistically observable at levels below the 50 mSv limit for occupationally exposed workers. Furthermore, an even lower limit of 4 mSv for the entire gestational period has been set to further minimize fetal doses for declared pregnant workers.

The effects of high level doses of prenatal irradiation on the growth and development of the human embryo and fetus are known and include:

- Gross structural malformations
- Growth retardation
- Embryo lethality
- Sterility
- CNS abnormalities
The developing CNS exhibits a particular sensitivity to ionizing radiation. The maximum sensitivity of the human brain occurs between 8 - 15 weeks gestation. This is the time of most rapid cell proliferation and migration of immature neurons. During this period a 43% frequency of mental retardation occurs for 1 Gy exposure with an apparent threshold in the range of 200 - 400 mGy. To a lesser extent a 10% increase in mental retardation is noted for 1 Gy exposure, in a fetus between 16 - 25 weeks gestation. No mental retardation effects have been observed when the fetus was exposed to these levels of radiation at < 8 weeks or > 25 weeks gestation.

**Radiation Exposure Limits At Dalhousie University**

Radiation workers at Dalhousie are normally considered to be persons working in controlled areas for which maximum permissible dose limits apply as they do for *A Person Who Is Not a Nuclear Energy Worker*. The majority of radiation workers at Dalhousie receive radiation doses far below these limits, as set out in the following table. The limits given are for doses due to *occupational* exposure only and do not include doses received as a result of medical or dental procedures.

It should be noted that the setting of a dose limit is equivalent to specifying a maximum acceptable level of risk. It is not acceptable to be exposed to the full extent of the limit if a lower dose can be reasonably achieved (ALARA).

### Maximum Permissible Dose Persons Who Are Not Nuclear Energy Workers

<table>
<thead>
<tr>
<th>Organ/Tissue</th>
<th>Millisieverts/year ( mSv/yr )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body</td>
<td>1</td>
</tr>
<tr>
<td>Lens of an eye</td>
<td>15</td>
</tr>
<tr>
<td>Skin</td>
<td>50</td>
</tr>
<tr>
<td>Hands and feet</td>
<td>50</td>
</tr>
</tbody>
</table>

The average dose received by an occupationally exposed worker at Dalhousie is < 0.2 mSv per year.

Compare:

- Allowable annual dose for Dalhousie workers: 1 mSv = $1.00
- Average dose received by Dalhousie workers: 0.2 mSv = 20 cents
Section 4 – Basic Radiation Protection

WHAT HAZARDS ARE ASSOCIATED WITH IONIZING RADIATION?

There are three main hazards associated with the types of radioactive materials used at Dalhousie. These are:

1) External radiation exposure

2) Skin contamination and/or deposition in the body (internal exposure)

3) Spread of contamination

External Exposure: [Diagram]

Internal Exposure: [Diagram]

A nuclear substance present in a working area is outside the body and thus constitutes a potential external exposure hazard. This nuclear substance becomes an internal exposure hazard when it is ingested, inhaled or absorbed through either intact skin or an open wound. Small quantities of radioactive material may represent an insignificant external hazard, however, once inside the body may concentrate in one or more organs referred to as a critical organ. These target areas will continue to be irradiated until the radioisotope has decayed or biologically eliminated from the body.

Exposure Pathways:

- Inhalation
- Ingestion
- Dermal Exposure
Working Safely – Responsibilities

Principal Investigators: Ensure that conditions of the permit are fulfilled and that safe laboratory practices are followed

1) Ensure that all staff using nuclear substances have been authorized to use nuclear substances and are listed as approved workers on the Nuclear Substance User permit.

2) Ensure that all staff using nuclear substances has been issued (if required), and use, a TLD and participate in bio screening programs as required.

3) Ensure that required personal protective equipment (PPE) is provided and used. PPE includes lab coats and disposable gloves and may also include (if indicated) whole body TLD’s, extremity TLD’s, and eye protection.

4) Designate specific work and storage areas for nuclear substances and ensure that these areas are kept clean, properly labeled, ventilated, adequately shielded and secure from unauthorized removal of nuclear substances.

5) Ensure that all staff using nuclear substances receives required radiation safety training from the institution and have been informed of the risks associated with exposure to ionizing radiation. Female staff shall be advised of the university’s Prenatal Exposure Policy.

6) Ensure that functional survey instrumentation is available to monitor both for exposure and contamination and that survey meters are calibrated annually as required by the CNSC under regulatory documents.

7) Maintain all required records as outlined in Dalhousie University’s Record Keeping Requirements Policy in the binder provided by the Radiation Safety Office unless otherwise exempted by the RSO. Records must be maintained for a minimum of six (6) years. Prior to disposal authorization must be received from both the RSO and the CNSC. Worker training records must be kept for three (3) years after the end of employment.

8) Report all radiation incidents to the RSO.

9) Ensure that a responsible designated alternate, approved by the RSO, is available to oversee nuclear substance work during your short or extended absences.

Users:

1) Become familiar with and comply with the University’s, and local lab safety, regulations.

2) Work in such a manner as to minimize exposure to yourself and your fellow workers.

3) Follow the three (3) basic radiation safety principles: time, distance, shielding.

4) Practice ALARA.

5) Report to your supervisor any incident involving a known or suspected radiation exposure, personal contamination, or a spill exceeding permissible limits.

6) Carry out required weekly contamination checks, and decontaminate if necessary.

7) A worker shall inform their supervisor and/or the RSO in writing of a pregnancy as soon as they become aware of it.
THE WORKPLACE

CAREFUL PLANNING

1) Be aware of the hazards associated with the nuclear substance you will be using:
   - Physical form
   - Chemical form
   - Chemical environment (is it volatile?)
   - Specific activity
   - Biodistribution
   - Radiotoxicity
   - Type of emission (α, β, γ)
   - Half life (T1/2)

2) Ensure that your lab has a current permit that includes the substances you will be using

3) Determine what personal monitors, survey equipment and/or shielding is required, for example:
   - Whole body monitoring (TLD)
   - Extremity monitoring (ring TLD)
   - Bioassay
   - Survey meter with GM detector
   - Survey meter with NaI detector
   - Lead vs plexiglass shielding

SAFE WORK HABITS

1) Do not bring unnecessary personal items into the laboratory

2) Become familiar with Dalhousie University’s Basic/Intermediate Level Laboratory - Nuclear Substance Safety posters

3) Follow the correct procedure for the receipt of a radioactive shipment

4) Have fume hood flow rates checked. Flow rate should be between 80 and 120 fpm

5) A protocol or recipe should be readily available at the workstation. Do a “dummy” run without radioactivity to check your procedures. Every movement should be carefully considered and rehearsed. The shorter the time the smaller the dose. This practice run will accomplish three things:
   - Discover any missing equipment & ensure proper labeling
   - Gain experience & increase efficiency
   - Evaluate your technique

6) Confine all contaminated items to an area designated for the purpose

7) **Cleanliness** and **good housekeeping** are the most effective elements (ALARA) of proper operating technique

8) To control the hazard from external radiation the following three principles are applied to ensure all work is ALARA:
Time: Accumulated time from external radiation is directly proportional to the amount of time spent in the area. Think of a trip to the beach as a comparison. If you spend a lot of time on the beach exposed to the sun you will get sunburn. If you spend less time in the sun and more time in the shade, your sunburn will be less severe.

Distance: The radiation field is directly proportional to the square of the distance from the source (inverse square law). Think of a trip to an outdoor concert as an example. You can sit directly in front of a speaker, 50 yards from the stage, or on the grass in the park across the street. If you sit in front of the speaker you may suffer some hearing damage, 50 yards from the stage you will be exposed to an average amount of sound, but across the street in the park, the sound is even further reduced and you might not even hear the concert or know what song is being played.

Shielding: The amount of shielding required depends on the type of radiation, the activity present and the dose rate which is acceptable outside the shielding material. Increased shielding around a source will decrease your exposure. Compare this to standing outside in the rain. If you stand outside in the rain without an umbrella you will get wet. But if you use an umbrella to shield you from the rain, you will remain dry.

For both the storage of radioisotope stocks and waste, it is essential that sufficient shielding be in place to maintain dose rates As Low As Reasonably Achievable (ALARA) and at least adequate to reduce levels to less than 2.5 microsieverts/hour.

ALARA: an acronym for as low as reasonably achievable - making every effort to maintain exposures to radiation as far below the dose limits as practical consistent with the purpose for which the licensed activity is undertaken, taking into account technology, the economics of improvements in relation to benefits to the public health and safety, and other socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public.

CONTROL OF RADIOACTIVE CONTAMINATION

A) Using a Survey Meter

Regulatory requirements state that a properly functioning survey meter capable of detecting the radionuclide energy at the criteria specified shall be used at all sites of licenced activity at all times. The meter must have been calibrated within the preceding 12 months. Survey meters are utilized to measure the dose rate/exposure rate (Sv).

PROCEDURE:

Performance Checks:

1) Verify the meter has been calibrated within the preceding 12 months

2) Verify that the physical condition of the meter is in good shape with no evidence of damage or broken parts

3) Conduct a battery check to verifying operational parameters. If the meter was left on the battery may not be functional and require replacing. Replace battery and recheck the meter

4) Ensure the meter background response reading is consistent with the typical facility background levels (0.2-0.4uSv/hr)
5) If any of the performance checks fail, do not use the meter and report it to your on-site radiation safety officer

**Calibration:**

Calibrations and efficiency determinations are to be performed under the supervision of a qualified person. It is the responsibility of the owner to ensure that the calibration is conducted in accordance with CNSC regulatory requirements.

**Records:**

Radiation detection equipment shall be routinely serviced according to the manufacturer’s instructions. Maintain a record of the service, calibration certificates and any references relating readings to regulatory criteria.

**B) Using a Contamination Meter**

Wherever there are unsealed nuclear substances being used, a properly functioning contamination meter capable of detecting radioactive contamination at the criteria specified on the licence for that nuclear substance shall be available.

**PROCEDURE:**

**Performance Checks:**

1) Verify that the **physical condition** of the meter is in good shape with no evidence of damage or broken parts.

2) Conduct a **battery check** to verifying operational parameters. If the meter was left on, the battery may not be functional and require replacing. Replace battery and recheck the meter.

3) Ensure the meter **background response** reading is consistent with the typical facility background levels (typically 30-60 counts per minute).

4) If any of the performance checks fail, do not use the meter and report it to radiation safety personnel.

**Calibration:**

Calibrations and efficiency determinations are to be performed by of a qualified person. It is the responsibility of the owner to ensure that the calibration is conducted in accordance with CNSC regulatory requirements.

**Records:**

Radiation detection equipment shall be routinely serviced according to the manufacturer’s instructions. Maintain a record of the service, calibration certificates and any references relating readings to regulatory criteria.
C) Contamination Surveys

Regular surveys of nuclear substance laboratories are required for the detection and cleanup of small amounts of loose contamination which may be present in spite of scrupulous care in technique and which would otherwise go unnoticed. It is a condition of the Nuclear Substance User Permit that contamination surveys (wipe testing) be conducted on a weekly basis during periods when work with nuclear substances is being conducted. A survey shall also take place at the end of each day of working with open sources of radiation for isotopes detectable with a contamination meter. Every permit holder is required to maintain a weekly record to indicate periods of both use and non-use. Contamination of laboratory furnishings and equipment presents both a potential health hazard to staff and a source of significant error in sensitive experiments. Routine procedures are set out below, and the management of spills is outlined in Section F of this manual.

Contamination monitoring instruments must be capable of making reproducible measurements at the license criteria limits. A minimum detection limit is approximately twice the background measurement. Advice should be sought from the RSO regarding appropriate instrumentation for monitoring these materials.

Direct Measurement of Contamination Using a Portable Meter:

Depending upon the detector and the radioisotopes, direct measurement is often convenient for monitoring large areas. Direct measurement instrument readings include both fixed and non-fixed contamination. Thus a reading which satisfies the license criteria gives a conservative estimate of non-fixed contamination.

By using a portable contamination monitor, it is possible to detect the presence of most gamma emitters and the more energetic beta emitters. This method allows the operator to easily survey large and/or irregular surfaces. Quantitative estimates of the amount of loose activity and the amount of activity per unit are not easily obtainable in this way and readings due to contamination may be masked by the background from nearby radiation sources. The sensitivity of these instruments for the detection of beta emitters is insufficient or poor for beta emitters such as $^3$H, $^{14}$C, $^{35}$S, $^{33}$P and gamma emitters such as $^{125}$I and $^{51}$Cr. Subject to these limitations, the use of a contamination monitor may be suitable and adequate to monitor for contamination in some laboratories. For further information on meters, consult the RSO if unsure of what type of meter to use.

A direct survey shall consist of the following:

- Monitor the locations marked on the plan of the working area by slowly passing the detector over each area
- Keep the detector face towards the surface being monitored and keep the distance between the detector and the surface as small as possible without touching (and possibly contaminating) the detector
- If contamination is detected, stop and obtain a measurement. Clean the area until the instrument measurement is below the licence criteria. A reading in excess of licence criteria after repeated cleaning is an indication of fixed contamination or a high radiation background
- Identify and mark the contaminated area on the plan
- Record the highest measurement for each area and the final measurement after decontamination
**Indirect Measurement of Contamination with Wipes:**

Non-fixed, transportable contamination on surfaces (which carries the potential hazard for internal exposure to personnel and for the spread of contamination) may be detected by wipe testing. Wipe testing is required on a weekly basis in laboratories where nuclear substances are regularly used. Where use is infrequent, wipe tests may be completed at the conclusion of each week’s experiment. To provide a continuous ongoing record of use/non-use periods documentation of non-use periods is required. Records of all surveys must be maintained in the binder provided by the Radiation Safety Officer.

**A wipe test program shall consist of the following:**

- Sketch a floor plan of the laboratory
- Mark test locations and number them on the floor plan. In addition to all areas and equipment where nuclear substances are used or stored, include such items as door handles, telephone receivers, taps, on/off switches on equipment, sinks, taps, floors, computer keyboards, etc.
- Use filter paper or cotton swabs moistened with a suitable solvent (water or alcohol) and wipe a representative area (often defined as 100 cm²) in each location. **Cotton swabs are not appropriate if your wipes will be counted by the direct survey method**
- Let wipes air dry before counting
- Measure the radioactivity on each wipe using suitable detection devices for the nuclear substance used in the laboratory – contact the RSO if in doubt as to which type of counting would be most appropriate
- Obtain background counts using a clean wipe

All wipe test results must be maintained for a one year after the expiry of the license and **must be available for inspection by the RSO and CNSC inspectors**. Maintain records of such tests in the binder provided by the Radiation Safety Officer.

**Wipe test records must include the following:**

- Date of measurement
- Make and model of instrument
- Monitoring locations
- Contamination monitoring results in Bq/cm² (before and after decommissioning procedures)
- For portable instruments, the results of operational checks and background measurement
- For non-portable instruments, blank and standard measurement results
- Instrument calibration data

If contamination is detected above the regulatory limits or above ALARA criteria, the location shall be decontaminated.
Repeat wipe testing or direct survey of the area in question and continue decontamination efforts until background levels are achieved or it has been determined that the contamination is fixed.

If the contamination has been determined to be fixed, and the area cannot be cleaned to meet the criteria, the contaminated surface must be sealed, removed or shielded until it meets the regulatory criteria.

Should there be an occasion where the weekly wipe test cannot be performed (e.g. equipment breakdown), this must be recorded in the record book. Send notification to the RSO of the situation.

Dalhousie University’s ALARA program requires that levels of loose contamination on all accessible areas not exceed 3 Bq/cm$^2$ and 30 Bq/cm$^2$ respectively for Class B & C radionuclides. It also requires that all levels of radiation be kept ALARA, which at Dalhousie University, should be able to be kept at the 2-3 times the background rule.

It is the responsibility of the Principle Investigator to ensure all necessary equipment is functioning properly. All radiation detection equipment should be routinely serviced according to the manufacturer’s instructions. All records of service and calibration certificates and any references relating readings to regulatory criteria must be maintained with the radiation safety records.

**D) Regulatory Limits for Radioactive Contamination**

The following are the CNSC license criteria for radioactive contamination:

The licensee shall ensure that for nuclear substances listed in the license “Appendix: Classes of Radionuclides”:

1) Non-fixed contamination in all areas, rooms or enclosures where unsealed nuclear substances are used or stored does not exceed:
   - 3 becquerels per square centimeter for Class A radionuclides;
   - 30 becquerels per square centimeter for all Class B radionuclides; or
   - 300 becquerels for all Class C radionuclides;

   averaged over an area not exceeding 100 square centimeters; and

2) Non-fixed contamination in all other areas does not exceed:
   - 0.3 becquerels per square centimeter for all Class A radionuclides;
   - 3 becquerels per square centimeter for all Class B radionuclides; or
   - 30 becquerels per square centimeter for all Class C radionuclides;

   averaged over an area not exceeding 100 square centimeters.
E) Action Levels for Radioactive Contamination

License conditions require that removable contamination does not exceed radionuclide-specific limits on accessible surfaces in occupational and public areas. Radionuclides are assigned classifications as follows:

- **Class A** - typically long lived and emit alpha radiation
- **Class B** - typically long lived and emits beta and gamma radiation
- **Class C** - typically short lived and emits beta and gamma radiation

### Classification of Selected Radionuclides

<table>
<thead>
<tr>
<th>Class</th>
<th>Radionuclide</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class A</strong></td>
<td>Ag-110m, Bi-210, Co-56, Cs-134, Cs-137, I-124, Lu-177m, Mn-52, Na-22, Po-210, Pu-238, Pu-239, Pu-240, Sb-124, Sc-46, Sr-82, U-234, U-235, U-238, V-48, Zn-65, All alpha emitters and their daughter isotopes</td>
</tr>
</tbody>
</table>

At Dalhousie University Class B and Class C radionuclides are typically used. In keeping with the ALARA policy contamination limits are set at regulatory limits for public areas and decommissioning limits, however, every effort should be made to maintain contamination levels to the 2-3 times background "Rule of Thumb". Contamination limits are based on activity per square centimeter.

<table>
<thead>
<tr>
<th>Class</th>
<th>Control Area Limit</th>
<th>Public Area/Decommissioning Limit</th>
<th>Dalhousie Contamination Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3 Bq/cm²</td>
<td>0.3 Bq/cm²</td>
<td>0.3 Bq/cm²</td>
</tr>
<tr>
<td>B</td>
<td>30 Bq/cm²</td>
<td>3 Bq/cm²</td>
<td>3 Bq/cm²</td>
</tr>
<tr>
<td>C</td>
<td>300 Bq/cm²</td>
<td>30 Bq/cm²</td>
<td>30 Bq/cm²</td>
</tr>
</tbody>
</table>

F) Relating Measurement Readings to Regulatory Criteria

1) The readings from contamination meters and non-portable instruments can be related to regulatory criteria (Bq/cm²) if the efficiency of the instrument for a specific radioisotope is known. To calculate Bq/cm² see Equation 1 below.

2) Instrument efficiencies for specific radioisotopes can be obtained from the manufacturer or determined using an appropriate standard of known activity. To calculate instrument efficiency see Equation 2 below.

3) For mixtures of radioisotopes, do all the calculations using the radioisotope for which the instrument has the lowest detection efficiency.
Equation 1: To calculate the measurement results in Bq/cm²

\[
\text{Removable Activity (Bq/cm}^2) = \frac{N - NB}{E \times 60 \times A \times (F)}
\]

Where:
N = the total count rate in counts per minute (cpm) measured directly or on the wipe.
NB = the normal background count rate (in cpm) from the survey instrument or the blank
E = the instrument efficiency factor (expressed as a decimal, i.e. for 26% efficiency, E=0.26) for the radioisotope being measured. Consult the manufacturer or determine using a radioactive source with a known amount of activity in a counting geometry similar to that used when surveying for contamination. For more information see section BB.9
60 = sec/min
A = area wiped (not to exceed 100 cm²) or area of the detector in cm² (for direct measurement)
F = the collection factor for the wipe (used only when calculating indirect wipe monitoring results). If F is not determined experimentally, a value of F=0.1 (i.e. 10%) shall be used.
A wipe efficiency of 10% is assumed for a wet wipe, 1% efficiency is assumed for a dry wipe.

Detector Efficiency:

The detector efficiency depends upon:
- The type of detector (GM, NaI Scintillation, Plastic Scintillation, Proportional)
- The detector size and shape
- The distance from the detector to the radioactive material
- The radioisotope and the type of radiation measured (alpha, beta and gamma radiations and their energies)
- The backscatter of radiation toward the detector
- The absorption of the radiation before it reaches the detector (by air and by the detector covering)

Equation 2: To determine the detector efficiency

1) Counting the standard source of known activity with your detector.

\[
\text{Efficiency} = \frac{\text{detector count rate} - \text{background count rate}}{\text{known activity of standard source}}
\]

2) Asking the manufacturer about the efficiency of the detector for your specific radioisotope(s).
**VIDEO ACTIVITY**

Please record the good/effective and poor/ineffective practices observed in this presentation.

<table>
<thead>
<tr>
<th>Good/Effective Practices</th>
<th>Poor/Ineffective Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
POINTS TO CONSIDER WHEN CONDUCTING A DIRECT SURVEY

1) Some radioisotopes may not be readily be detected

2) High radiation fields

3) Immediate indication

4) Non-specific

5) Large area to survey
POINTS TO CONSIDER WHEN CONDUCTING AN INDIRECT SURVEY

1) Low energy beta emitters

________________________________________________________________________________________________________________________________________________________________________________________

2) High radiation fields

________________________________________________________________________________________________________________________________________________________________________________________

3) Immediate indication

________________________________________________________________________________________________________________________________________________________________________________________

4) Generally specific

________________________________________________________________________________________________________________________________________________________________________________________

5) Accuracy depends on

________________________________________________________________________________________________________________________________________________________________________________________

6) Alternative to using LA or γ counter

________________________________________________________________________________________________________________________________________________________________________________________

If an individual is planning to calculate the approximate quantity of contamination in terms of area, he/she must define when swiping. Counter and wipe efficiencies must be taken into consideration. The following formula can be used to determine the quantity of contamination.

**FORMULA FOR DETERMINING APPROXIMATE CONTAMINATION LEVEL**

Bq/cm² = CPM net [C.E. x 60 x 100 x W_eff]

Where: Bq/cm² = Becquerel per centimeter squared
C.E. = counting efficiency
60 = 60 seconds
100 = area of 100 cm² wiped
W_eff = wipe efficiency (10% for a wet wipe; 1% for a dry wipe)
COMPARISON

When the two methods of conducting a contamination survey are compared by means of a split screen here is the method chosen and the reasons why.

1) Low energy beta emitter - Indirect method

2) High radiation field - Indirect method

3) Need to know immediately - Direct method

4) Need to know the radioisotope - Indirect method

5) Large area to survey - Both direct & indirect
CONTAMINATION SURVEYS

1) General laboratory survey

_______________________________________________________________________________________

_______________________________________________________________________________________

_______________________________________________________________________________________

2) Immediate work area

_______________________________________________________________________________________

_______________________________________________________________________________________

_______________________________________________________________________________________

3) Personal survey

_______________________________________________________________________________________

_______________________________________________________________________________________

_______________________________________________________________________________________

4) Logbooks

_______________________________________________________________________________________

_______________________________________________________________________________________

_______________________________________________________________________________________
CONCLUSION

The keys to contamination detection are:

1) Frequent monitoring

2) Selecting appropriate method

3) Selecting appropriate instrumentation

4) Instrument has been calibrated

5) Determine area/equipment to be surveyed

6) Use correct technique

7) Maintain through documentation

8) Interpret results

YOU ARE THE KEY TO CONTAMINATION CONTROL !!
Section 5 - The Key To Contamination Detection & Control

Introduction

This training module is designed for interactive discussion on radioactive contamination that can be used in your everyday work procedure.

The video tape presentation will require your concentration and visual skills in identifying good/effective and poor/ineffective contamination detection procedures. These procedures should be noted in the spaces provided in the workbook.

The instructor will provide additional information on conducting surveys of general laboratories, work areas and personal surveys. You may wish to take notes on this information for future reference.

How Can a Worker Protect Themselves From Contamination?

- Never work with unprotected cuts or breaks in the skin, particularly on the hands and forearms. Never use any mouth operated equipment in any area where unsealed radioactive material is used. Always store compounds under the conditions recommended. It should be noted that solutions of radioactive compounds are supplied by manufacturers packaged to meet transport regulations. Always follow recommended package receipt procedures. Refer to CNSC poster Guidelines For Handling Packages Containing Nuclear Substances INFO-0744

- Always keep active and inactive work separate. Consideration should be given to maintaining specific rooms or at the very least specific workbenches solely for radioactive work.

- Lab coats are designed to offer spill protection to the wearer and their use is mandatory when working with radioactive materials. In order to function properly, the lab coat must be buttoned completely and the sleeves rolled fully down. Cuffs should be sealed with gloves. Lab coats must not be worn outside the laboratory and must never be worn in areas in which food is consumed if there is any chance that the lab coat is contaminated.

- The use of disposable gloves when working with radioactive material is mandatory. Gloves need to be checked often for contamination and small punctures that may have developed. Disposable gloves are prone to wear at the fingertips. Disposable gloves must never be worn outside the laboratory. Working with certain compounds may require double gloving (specifically $^{125}$I and $^3$H), replacing the outer pair at least every 30 minutes. Double gloving is generally recommended when working with any radioactive material.

- It is recommended that long pants be worn to provide splash protection for the lower legs. Shoes that cover the entire foot are required in all research areas. Sandals, clogs, etc., do not offer adequate protection in the event of a spill, nor do they offer protection from falling objects.

- Safety glasses, goggles or face guards should be worn when there is a possibility of splashing material into the eyes. It is good practice to wear safety glasses when working with stock solutions of high energy beta emitters in order to reduce the external radiation dose to the eyes.
CONTAMINATION CONTROL

Types of Contamination:

1) Airborne - the release of a radioactive gas, vapor, dust, mist or aerosol into the breathing space

2) Surface - contamination on the exterior surface of a person, equipment or material primarily caused by poor handling techniques and housekeeping as well as accidental spills.
   - Loose (removable) - easily transferable to other surfaces which could then lead to internal contamination of personnel.
   - Fixed - not readily removed. Depending on the radioisotope and activity fixed contamination may pose an external radiation hazard.

Means To Prevent Contamination:

1) Identify source characteristics

2) Preplan your experiment

3) Have available and wear personal protective equipment (PPE)

4) Proper work area design
   - Define the area with warning tape and labels
   - Designate a sink for disposal and wash up
   - Use fume hood when operations produce vapors, dusts, sprays or gases
   - Use spill trays of an appropriate size
   - Line work surfaces with absorbent paper
   - Minimize the movement of equipment and materials in and out of the active area
   - Identify equipment and materials used for radioactive work
   - Check equipment for contamination at the end of each work day

5) Waste disposal
   - Avoid sloppy pouring of liquids into disposal containers which must be sitting in a secondary container
   - Volatile waste must be stored in a sealed container
   - Trays used as a secondary container must be checked weekly for contamination
   - Absorbent liners should be changed frequently
   - If liquid is stored in a glass container, sufficient absorbing material; such as sawdust, to absorb the contents must be used

6) To prevent unauthorized removal, label containers and equipment with the following information
   - Nuclear substance
   - Date
   - Activity
   - User
**Means to Limit Contamination:**

1) Early detection - achieved by frequent monitoring. Frequency will depend on:

- Quantity of nuclear substance used
- Radiotoxicity
- Type of manipulation
- History of lab contamination incidents

**DIRECT MONITORING FOR CONTAMINATION**

Direct measurement means the use of portable radiation detection instruments to detect both fixed and removable (loose) contamination on a surface. Direct measurement may be used when background radiation levels are negligible compared to licence criteria. While the direct monitoring method has the advantage of allowing the operator to easily survey large and irregular surfaces, there are also disadvantages. This method does not indicate if the contamination is fixed or loose and cannot be used in high background areas. It cannot detect $^{3}H$ and may not be very effective with low energy beta emitters such as $^{14}C$ and $^{35}S$. The main advantage of the direct monitoring method over wipe testing is the speed of operation. For best results, the weekly wipe test should be complemented by daily spot checks with a portable contamination monitor.

The readings from portable contamination monitors can be related to licence criteria if the efficiency of the instrument for a specific nuclear substance is known. For mixtures do all calculations using the nuclear substance for which the instrument has the lowest detection efficiency.

When performing direct monitoring, the accompanying form is to be used. Negative results (< 0.5 Bq/cm$^2$) require a check (√), positive results must be noted with follow up action taken.

e.g. Detector efficiency for $^{32}P$ ~20 %

$^{35}S$, $^{14}C$ ~10 %
Section 6 – Radioactive Decontamination Procedures

Introduction:

Regardless of your level of training and experience in the use of nuclear substances, spills will almost certainly occur on occasion. While these events will hopefully be rare, it is essential for all nuclear substance users to be familiar with safe procedures for managing them.

You will review basic principles for the safe use of open source nuclear substances and the necessary background information upon which your approach to the management of accidental spills will depend. This foundation leads to the identification of the assessment techniques required in planning cleanup procedures. It should be obvious that the appropriate use of the survey meter is a central element in detecting contamination in the workplace and in monitoring clean up procedures.

DECONTAMINATION PRINCIPLES

Radioactive contamination is the deposition of radioactive material in any place where it is not wanted. Decontamination is the process of removal of contamination.

Decontamination can prove to be an expensive operation, in terms of both time and money spent and hence the main aim in the design and operation of any working area should be to reduce the possibilities of any contamination to the absolute minimum. Nevertheless, when working with a nuclear substance, a certain amount of contamination will inevitably arise. One of the principal objectives in any nuclear substance laboratory must be to prevent the attachment of contamination to surfaces and to facilitate the removal of the contamination. This may be accomplished by:

- Appropriate segregation of operations involving open sources
- Minimizing contamination, controlling the spread of contamination & decontamination
- The use of appropriate protective clothing
- The provision of smooth impermeable surfaces in all working places
- The use of appropriate monitoring instruments to detect and effectively deal with contamination incidents

Loose contamination will not be tolerated on exposed surfaces. Ideally, all contamination should be removed; however, there are considerations which should be taken into account in determining the degree of decontamination required. Some considerations are:

- Skin - while it is ideal to remove the entire contamination, be aware that drastic measures in certain cases could result in such damage to the skin that the radioactive material could gain entry into the body, thus giving rise to an internal hazard
- Equipment - when a short lived nuclear substance is involved it might be more advantageous to store the contaminated object temporarily. In other cases it might be more economical to dispose of the item as radioactive waste.
The fundamental principles which are applicable to all decontamination procedures are:

- Wet decontamination methods should always be used in preference to dry ones
- Mild decontamination methods should be tried before resorting to treatment which can damage the surfaces involved
- Precautions must always be taken to prevent the further spread of contamination during clean up procedures
- Where possible, contamination involving short lived radioisotopes should be isolated for decay
- **IF PERSONNEL ARE SERIOUSLY INJURED, FIRST AID ALWAYS TAKES PRECEDENT. FIRST AID SHOULD BE PERFORMED, DECONTAMINATION EFFORTS CAN FOLLOW.**

**UNCONTROLLED, UNDETECTED RADIOACTIVITY (CONTAMINATION) HAS THE POTENTIAL FOR BECOMING INTERNALLY DEPOSITED.**
A) **Preparation Steps.** Assemble at least one decontamination kit for each radioisotope laboratory. Items to be included in each kit are as follows:

- Radioactive warning sign (1) and tape (1 roll)
- Disposable gloves (1 box)
- Plastic bags (4 of each): small, medium, and large
- Masking tape (1 roll)
- Grease pencil (1)
- Forceps (2) and tongs (1)
- Gauze sponges (1 package)
- Detergent (1 bottle)
- Scouring powder (1 container)
- Identification tags (6)
- Scissors (1 pair)
- Filter paper wipes or cotton applicators (20 in total)
- Absorbent pads (6)
- Floor plan of your work area - made in advance (1)
- Nail brush or test tube brush (1)
- Bar soap or dermabrasive cleaner (1)
- Tissues (1 box)
- Paper towel (1 roll)
- Disposable plastic aprons (4)
- Spare batteries (2)

B) **Establish a cleanup procedure.** Your objectives are:

1) Minimize the amount of radioactive material entering the body
2) Prevent the spread of contamination from the spill area
3) Remove any contamination on personnel
4) Start area decontamination under qualified supervision. Inexperienced personnel should not attempt unsupervised decontamination

C) **Spill Clean-Up Procedure**

**Stage 1: DON'T PANIC**

1) Notify all persons in the room. Instruct them to move to an alternate area in the room until surveyed for contamination
2) Remove gloves, place absorbent pad over spill area. Call the supervisor and the Radiation Safety Officer (if required)
3) Post a radiation warning sign on the door
4) Wait for help to arrive (supervisor and/or RSO)
Stage 2:

1) Survey all persons for contamination - if uncontaminated allow them to leave
2) Survey spill area where appropriate for contamination levels. Record counts on floor plan

Stage 3:

1) Apply fresh gloves and shoe covers (if necessary)
2) Outline spill area with a grease pencil
3) Kneeling on an absorbent pad, using tongs soak up liquid with gauze working from the outside towards the center. Blot with paper towels
4) Supervisor or RSO will survey and record results
5) Apply detergent, wipe with gauze and paper towels
6) Supervisor or RSO will survey and record results
7) Apply scouring powder, wipe with gauze and paper towels
8) Supervisor or RSO will survey and record results
9) If count rates are acceptable (< 2x background), remove gloves, etc. and place in garbage bag
10) Label all disposables with ID tag
11) Do wipe tests over spill area
12) Cover area with absorbent pad and tape edges down
13) Supervisor or RSO will monitor worker
14) Worker will monitor supervisor or RSO
15) Count and report results of wipe tests
16) If wipe tests are negative remove warning sign from door
17) Remove disposable pad from spill area
18) Replenish decontamination kit
19) Prepare a written report
## DECONTAMINATION OF PERSONNEL & EQUIPMENT

<table>
<thead>
<tr>
<th>Contaminated Area</th>
<th>Decontaminating Agent</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin &amp; hands</td>
<td>Mild soap &amp; water</td>
<td>Wash 2-3 min. &amp; monitor. Do not wash more than 3-4 times</td>
</tr>
<tr>
<td></td>
<td>If necessary, follow by soft brush, heavy lather, tepid water</td>
<td>Use light pressure with heavy lather</td>
</tr>
<tr>
<td></td>
<td>Lava soap &amp; water</td>
<td>Wash 2 min., 3 times. Rinse &amp; monitor. Use care not to scratch or erode the skin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apply lanolin or hand cream to prevent chapping</td>
</tr>
<tr>
<td></td>
<td>A mixture of 50% Tide &amp; 50% cornmeal.</td>
<td>Make into a paste. Use with additional water with a mild scrubbing action. Avoid scratching and eroding the skin</td>
</tr>
<tr>
<td></td>
<td>Weak acid solution such as vinegar</td>
<td>Apply to skin contaminated with P-32/P-33</td>
</tr>
<tr>
<td></td>
<td>Cotton glove covered by disposable poly glove.</td>
<td>Seal at wrist to promote sweating</td>
</tr>
<tr>
<td>Wounds</td>
<td>Running tap water. Report to medical Officer &amp; RSO asap</td>
<td>Wash the wound with copious amounts of water immediately. Spread the edges of the wound to permit flushing action by the water</td>
</tr>
<tr>
<td>Ingestion by swallowing</td>
<td>Induce vomiting. Drink large volumes of liquid to dilute activity.</td>
<td></td>
</tr>
<tr>
<td>Clothing</td>
<td>Wash if levels permit</td>
<td>Use standard laundering procedures</td>
</tr>
<tr>
<td>Glassware</td>
<td>Soap or detergent &amp; water</td>
<td>Dispose of wash water to designated drain</td>
</tr>
<tr>
<td></td>
<td>Commercial decontaminating solutions</td>
<td>Dispose of wash water to designated drain</td>
</tr>
<tr>
<td>Laboratory tools</td>
<td>Detergent &amp; water, steam cleaning</td>
<td>Use mechanical scrubbing action</td>
</tr>
<tr>
<td></td>
<td>Commercial decontaminating solutions</td>
<td></td>
</tr>
<tr>
<td>Specific materials such as rubber, plastic, leather, ceramic tile, paint, concrete, wood, etc.</td>
<td>Contact the RSO</td>
<td>Contact the RSO</td>
</tr>
<tr>
<td>Traps &amp; drains</td>
<td>1. Flush with water</td>
<td>Follow all 4 steps</td>
</tr>
<tr>
<td></td>
<td>2. Scour with rust remover</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Soak in a soln of nitric acid</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Flush again</td>
<td></td>
</tr>
</tbody>
</table>
## RADIATION INCIDENT REPORT

**To:** Radiation Safety Office

**From:** ____________________________________________
Principal Investigator

**Date:** __________________________

### Location Of Incident:

<table>
<thead>
<tr>
<th>Building</th>
<th>Room #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Nuclear Substance(s) Involved:** ________________

**Estimated Activity:** _______

**Date/Time Of Incident:** ________________/

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Name Of Person Making Report:** ________________

**Instrument Used To Check For Contamination:** ________________

---

1. **Give a brief description of the incident:**

   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________

2. **Name of individual(s) present:**

   ____________________________________________
   ____________________________________________
   ____________________________________________

3. **Injuries sustained:**

   _______ (yes)  _______ (no)

4. **Personnel contamination:**

   _______ (yes) (describe)  _______ (no)

   ____________________________________________
   ____________________________________________

5. **Action Taken:** (see attached report)

---

Radiation Safety Training Manual 50
6. Statement Of The Cause(s):

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

7. Any Remedial Action Taken:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

8. Additional Comments:


RADIOACTIVE SPILL CONTAMINATION/CLEAN UP SURVEY

Decontamination completed at _____:____ on _____-_____-

<table>
<thead>
<tr>
<th>Location</th>
<th>Pre-Clean cpm/dpm</th>
<th>Post clean cpm/dpm</th>
<th>Activity Present</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Name: _________________________________________
Section 7 – Radiation Safety Policies

ALARAN STATEMENT

**ALARA – As Low As Reasonably Achievable** means making every reasonable effort to maintain exposures as far below the regulated dose limits as is practical, consistent with the purpose for which the licensed activity is undertaken. The state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, other societal and socioeconomic considerations, and utilization of nuclear energy and licence material in relation to the public interest should be taken into account.

Dalhousie University is committed to limiting radiation exposures to staff, students, and the public, from the use of nuclear substances and radiation emitting devices in research by complying with ALARA procedures. The Radiation Safety Committee and the Radiation Safety Officer will advise and assist in all matters of radiation safety. The Committee will recommend to University administration through the Radiation Safety Officer, policies and procedures to be required for maintaining radiation exposures ALARA through safe handling, storage, use, transport and disposal of radiation sources and will assist in the interpretation of the *Nuclear Safety & Control Act*, Regulations and Licence conditions.

Policies and procedures are delineated in the Dalhousie University Radiation Safety Manual.
Title: ALARA Policy
Number: RSP – D.1
Date: January 11, 2001, revised December 6, 2005, August 2007, Revised March 2017

Introduction:

The Radiation Protection Regulations require implemented measures to keep doses received by workers and members of the public from exposure to sources of radiation As Low As Reasonably Achievable (ALARA). This requires taking every reasonable effort to maintain exposures as far below the regulated dose limits as practical, consistent with the purpose for which the licenced activity is undertaken, and considering social and economic factors. It is insufficient to simply respect the appropriate dose limits.

Section 4(a) of the Radiation Protection Regulations requires ALARA principles to be applied through the implementation of:

(i) Management control over work practices:

It is essential that all levels of management, in particular the senior level of the organization, commit to a policy of safety and good radiation protection to keep all doses ALARA.

(ii) Personnel qualification and training:

It is essential that workers commit to radiation safety. Relevant and adequate training programs for all personnel in the organization are required. Sufficient instruction and training enable workers to understand the risk from exposure to radiation and the methods of controlling doses.

(iii) Control of occupational and public exposure to radiation:

Management commits to provide appropriate resources, such as staff, equipment and facilities in order to contribute to the adequate control of doses. Regular review of dose records and other appropriate dose indicators will be performed. Technological advances in protective equipment and instrumentation should be monitored to identify improved methods of dose reduction.

(iv) Planning for unusual situations:

For work projects in areas where the existing or potential radiation hazards may result in workers accumulating significant doses, detailed work plans should be developed.
Responsibilities:

Administration:

a) The Administration of Dalhousie University is responsible to ensure necessary resources and organizational structures are maintained to support and foster a radiation safety program that keeps individual and collective doses ALARA. This responsibility includes maintaining a Radiation Safety Officer (RSO), a Radiation Safety Committee, and all necessary policies and procedures.

b) The RSO will manage the day to day operations of the Radiation Safety Program including developing and maintaining necessary policies and procedures, personnel dose records, inspections, laboratory self-inspections, internal permitting system, and training.

c) Modifications to operating, maintenance, and experimental procedures, as well as changes in equipment and facilities will be made if they will reduce exposures, unless the cost is considered unjustified. If modifications have been recommended but not implemented, justification will be provided for lack of implementation.

d) The Radiation Safety Committee will review the ALARA program during committee meetings. Recommendations and opportunities for improvement to the ALARA program will be determined as appropriate.

e) The Director of EHS will present an annual report of the radiation safety program to the VP Finance and Administration.

Obligation of the Licensee:

a) To ensure the presence of enough qualified workers to carry on the licensed activity safely and in accordance with the Nuclear Safety and Control Act, the regulations made under the Act and the Nuclear Substances and Radiation Devices Licence conditions.

b) To train workers to carry on the licensed activity in accordance with the Act and regulations.

c) To take all reasonable precautions to protect the environment and the health and safety of persons and to maintain security.

d) To provide the devices required by the Act and regulations and maintain them within the manufacturer’s specifications.

e) To require that every person at the site of the licensed activity uses equipment, devices, clothing and procedures in accordance with the Act and regulations.

f) To take all reasonable precautions to control the release of radioactive nuclear substances or hazardous substances within the site of the licensed activity and into the environment as a result of the licensed activity.
g) To implement measures for alerting the licensee to the illegal use or removal of a nuclear substance, prescribed equipment or prescribed information, or the illegal use of a nuclear facility

h) To implement measures for alerting the licensee to acts of sabotage or attempted sabotage anywhere at the site of the licensed activity

i) To instruct the workers on the physical security program at the site of the licensed activity and to their obligations under that program

j) To keep a copy of the Act and the regulations made under the Act that apply to the licensed activity readily available for consultation by the workers

Workers:

a) To use equipment, devices, facilities, and clothing for protecting the environment or the health and safety of persons, or for determining doses of radiation, dose rates or concentrations of radioactive nuclear substances, in a responsible manner and in accordance with the Act, the regulations made under the Act and the Nuclear Substance User Permit.

b) To comply with the measures established by the licensee to protect the environment and the health and safety of persons, maintain security, control the levels and doses of radiation, and control releases of radioactive nuclear substances and hazardous substances into the environment.

c) To promptly inform the licensee or the worker’s supervisor of any situation in which the worker believes there may be:
   
   ▪ A significant increase in the risk to the environment, or the health and safety of persons.
   
   ▪ A threat to the maintenance of security or an incident with respect to security.
   
   ▪ Failure to comply with the Act, the regulations made under the Act or the permit.
   
   ▪ An act of sabotage, theft, loss, or illegal use or possession of a nuclear substance or prescribed information.
   
   ▪ A release into the environment of a quantity of a radioactive nuclear substance or hazardous substance that has not been authorized by the licensee

d) Observe and obey all notices and warning signs posted by the licensee in accordance with the Radiation Protection Regulations.

e) Take all reasonable precautions to ensure the worker’s own safety, the safety of the other persons at the site of the licensed activity, the protection of the environment, the protection of the public and the maintenance of security.
Procedure:

1. The RSO, in conjunction with the Radiation Safety Committee will enforce these procedures.

2. All occupationally exposed workers will be provided with a copy of the ALARA policy. It will be made available to each research group as part of the Radiation Safety Policies and will be available for review in the Radiation Safety Manual, which can be located at www.dal.ca/safety.

3. All new occupationally exposed workers will participate in the first Radiation Safety Training course available after joining a research group, unless otherwise exempted by the RSO.

4. The RSO will review the qualifications of each Principal Investigator (PI) with respect to the types and quantities of nuclear substance requested, methods of use, suitability of laboratory space, availability of required shielding, dosimetry, and monitoring equipment.

5. The RSO will review all planned laboratory construction and renovations where nuclear substance work is to be performed prior to submission of plans to the Canadian Nuclear Safety Commission (CNSC) to ensure that the requirements of CNSC’s Regulatory Document GD-52 “Design Guide for Nuclear Substance Laboratories and Nuclear Medicine Rooms” are met.

6. The RSO will review quarterly, the occupational radiation exposures of all monitored workers. The following charts provide the CNSC prescribed dose limits and Dalhousie University’s action levels. Dalhousie’s action levels are per quarter. These action levels are the highest expected values for non-NEW’s and NEW’s. If an internal action level is exceeded for the quarter, the RSO will alert the individual, investigate the situation and decide if action is warranted. No reporting to the CNSC is required. If the prescribed dose limits from the CNSC are exceeded, an immediate report will be filed with the CNSC, followed by an investigation report within 21 days.
<table>
<thead>
<tr>
<th>Item</th>
<th>Person</th>
<th>Period</th>
<th>CNSC Effective Dose Limits (mSv)</th>
<th>Dalhousie Action Level (mSv/quarter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nuclear energy worker (NEW) including a pregnant nuclear energy worker</td>
<td>(a) One-year dosimetry period</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) Five-year dosimetry period</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Pregnant Nuclear Energy Worker</td>
<td>Balance of the pregnancy</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>A person who is not a nuclear energy worker</td>
<td>One calendar year</td>
<td>1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organ or Tissue</th>
<th>Person</th>
<th>Period</th>
<th>CNSC Equivalent Dose Limits (mSv)</th>
<th>Dalhousie Action Level (mSv/quarter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lens of an eye</td>
<td>(a) Nuclear energy worker</td>
<td>One-year dosimetry period</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Any other person</td>
<td>One calendar year</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>Skin</td>
<td>(a) Nuclear energy worker</td>
<td>One-year dosimetry period</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Any other person</td>
<td>One calendar year</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Hands and feet</td>
<td>(a) Nuclear energy worker</td>
<td>One-year dosimetry period</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Any other person</td>
<td>One calendar year</td>
<td>50</td>
</tr>
</tbody>
</table>
7. Licence conditions require that removable contamination does not exceed nuclear substance-specific limits on accessible surfaces in occupational and public areas.

Nuclear substances are assigned classifications as follows:

- **Class A** - typically long lived and emits alpha radiation
- **Class B** - typically long lived and emits beta or gamma radiation
- **Class C** - typically short lived and emits beta and gamma radiation

### Classification of Selected Radionuclides

<table>
<thead>
<tr>
<th>Class</th>
<th>Radionuclide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>Ag-110m, Bi-210, Co-56, Co-60, Cs-134, Cs-137, I-124, Lu-177m, Mn-52, Na-22,</td>
</tr>
<tr>
<td></td>
<td>Po-210, Pu-238, Pu-239, Pu-240, Sb-124, Sc-46, Sr-82, U-234, U-235,</td>
</tr>
<tr>
<td></td>
<td>U-238, V-48, Zn-65 All alpha emitters and their daughter isotopes</td>
</tr>
<tr>
<td>Class B</td>
<td>Au-198, Ba-133, Br-82, Ce-143, Co-58, Cu-67, Fe-59, Hg-194, Hg-203, I-131,</td>
</tr>
<tr>
<td></td>
<td>Ir-192, La-140, Mo-99, Nb-95, Pa-233, Ra-223 Re-186, Re-188, Ru-103, Sb-122,</td>
</tr>
<tr>
<td></td>
<td>Sm-153, Sr-90, Xe-127, Y-86, Y-90, Yb-169, Zr-89, Zr-95</td>
</tr>
<tr>
<td>Class C</td>
<td>C-11, <strong>C-14</strong>*, <strong>Ca-45</strong>*, Cd-109, Ce-141, Cl-36, Co-57, <strong>Cr-51</strong>*, Cu-60,</td>
</tr>
<tr>
<td></td>
<td>Cu-61, Cu-64, <strong>F-18</strong>*, Fe-55, Ga-67, Ga-68, Ge-68, H-3*, I-123*, I-125*,</td>
</tr>
<tr>
<td></td>
<td>In-111*, In-113m, In-114, K-42, Kr-85, Lu-177, Mn-52m, Mn-56, N-13, Na-24,</td>
</tr>
<tr>
<td></td>
<td>Nb-98, Ni-63, O-15, <strong>P-32</strong>*, P-33*, Pd-103, Pr-144, Pu-241, Rh-106, <strong>S-35</strong>*</td>
</tr>
<tr>
<td></td>
<td>Sc-44, Sn-113, Sr-89, Tc-94m, Tc-99, <strong>Tc-99m</strong>*, Te-127, Ti-201, V-49, W-181,</td>
</tr>
<tr>
<td></td>
<td>W-188, Xe-133, Zn-63</td>
</tr>
</tbody>
</table>

* These radionuclides are commonly used at Dalhousie University.

<table>
<thead>
<tr>
<th>Class</th>
<th>Control Area Limit</th>
<th>Public Area/ Decommissioning Limit</th>
<th>Dalhousie Contamination Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3 Bq/cm²</td>
<td>0.3 Bq/cm²</td>
<td>0.3 Bq/cm²</td>
</tr>
<tr>
<td>B</td>
<td>30 Bq/cm²</td>
<td>3 Bq/cm²</td>
<td>3 Bq/cm²</td>
</tr>
<tr>
<td>C</td>
<td>300 Bq/cm²</td>
<td>30 Bq/cm²</td>
<td>30 Bq/cm²</td>
</tr>
</tbody>
</table>

At Dalhousie University Class C nuclear substances are typically used. To comply with ALARA, contamination limits are set at regulatory limits, however every effort should be made to maintain contamination levels below the 2-3 times background “rule of thumb”. Contamination limits are based on activity per square centimeter. Wipe testing must be completed at minimum within 7 days of isotope usage. Surveys of the area will be conducted daily for those detectable isotopes.

8. Each research group holding a Nuclear Substance User Permit, will be required to conduct a nuclear substance laboratory self-inspection, twice per calendar year. Any non-compliances shall be remediated in a timely fashion. The self-inspection report will be reviewed by the RSO. An audit of the laboratories shall be conducted by the RSO at regular intervals, on a risk based approach. The **Internal Review and Enforcement Policy** will be applied as required.
Introduction:

All researchers who work with nuclear substances or radiation devices shall be appropriately designated as authorized radiation workers and provided radiation safety training in accordance with the identified hazards of their specific job.

At Dalhousie University, there are two classifications of radiation workers. Nuclear Energy Workers (NEW’s) and Non-Nuclear Energy Workers (Non-NEW). Individuals working with radiation that have the potential for receiving annual doses exceeding the general public limits, will be designated as NEW’s. Those individuals working with radiation who do not have the potential for receiving annual doses exceeding the general public limits, will be designated as Non-NEW’s. The Radiation Safety Officer (RSO) will be responsible to determine the appropriate designation.

The Radiation Protection Regulations prescribe that the following be provided to all designated NEW’s in writing:

1. Notification that they are registered as NEW’s.
2. Information regarding the risk to individuals exposed to radiation, as well the risk associated with exposure of an embryo and fetus.
3. Information regarding the risks to pregnant individuals and their obligation to declare a pregnancy.
4. The dose limits for NEW’s as prescribed by the regulations.
5. The dose records for the individual.
6. Rights and obligations of pregnant NEW’s:
   a. Every NEW who becomes aware that she is pregnant shall immediately inform the RSO in writing.
b. The licensee will make accommodations for the pregnant NEW that will not occasion costs or business inconvenience constituting undue hardship to the licensee.

The Radiation Protection Regulations also state that every licensee shall obtain from each NEW a written acknowledgement that the worker has received the information as prescribed by the regulations.

As per regulation, every licensee shall use a licensed dosimetry service to measure and monitor the doses of radiation received by and committed to NEW’s. The following information must be collected for every registered NEW in order to obtain a radiation monitoring badge.

- Full name (all given names, surname, and previous surnames)
- Social insurance number
- Gender
- Date and place of birth (province/state and country)

The information is protected under privacy legislation.

See Ascertaining and Recording Doses Policy for more information on radiation badges.

PROCEDURE

1. It is the Principle Investigators (PI) responsibility to register ALL individuals with the RSO. Completion of the Radiation Worker Registration Form is required to be submitted to the RSO. This form is located on the Environmental Health and Safety website.

2. The RSO will determine the designation of the radiation worker based on the type of work, the isotopes and quantities used. Those having the potential to exceed the general public limits of greater than 1mSv per year, will be designated as a NEW. Those individuals who would fall under the public limit will be designated as a Non-NEW.

3. The RSO will notify all individuals of a NEW designation and will ensure the Worker Classification Policy is available to them. They will be instructed to review the policy, review the Radiation Protection Regulations, read the information presented to them by the RSO, sign the Notification of Nuclear Energy Worker Status form, declaring their acknowledgement as an NEW, and that they were informed of the risks as prescribed by the Radiation Protection Regulations.

4. A radiation detection badge (dosimeter) will be issued for the individual as required. All information necessary to receive a dosimeter will be contained on the Radiation Worker Registration Form.

5. Every NEW who becomes aware that she is pregnant shall immediately inform the RSO in writing. Refer to the Prenatal Exposure Policy for further direction.
6. All forms will be maintained by the RSO.

7. All dosimeter occupational radiation exposure reports will be reviewed by the RSO on a quarterly basis. Those individuals reaching internal action levels will be notified of the results. If warranted, the RSO will investigate the situation and determine if any corrective measure need to be put into place. All exposure reports are sent to the individual departments for the radiation workers to view their personal occupational dose exposures.
Notification of Nuclear Energy Worker Status

In accordance with the *Nuclear Safety and Control Act* (NSCA) and its regulations, this is to inform you that you are a Nuclear Energy Worker (NEW). As defined in the NSCA, a NEW is a person who is required, in the course of the person’s business or occupation in connection with a nuclear substance or nuclear facility, to perform duties in such circumstances that there is a reasonable probability that the person may receive a dose of radiation that is greater than the prescribed limit for the general public. The general public limit is 1mSv per year.

As required by the *Radiation Protection Regulations*, Section 7, I have been informed in writing:

1. The risks associated with radiation to which I may be exposed during the course of my work, including the risk associated with the exposure of an embryo and fetus.
2. The applicable dose limits as specified in the regulations.
3. My expected radiation dose levels.
4. For females, my rights and obligations should I become pregnant (*Prenatal Exposure Policy*).

☐ I acknowledge that I have been designated as a Nuclear Energy Worker (NEW).

☐ I understand the risks, my obligations and the radiation dose limits and levels that are associated with being designated a NEW.

☐ I have reviewed the documents provided by the RSO to review the risks of working with radiation as well as the Radiation Protection Regulations at [http://laws-lois.justice.gc.ca/PDF/SOR-2000-203.pdf](http://laws-lois.justice.gc.ca/PDF/SOR-2000-203.pdf).

Worker Name: _______________________________________ Sex: □ M □ F

Signature of Worker: _______________________________________ 

Date: ________________________________________________

Radiation Safety Officer Name: ________________________________________

Signature of Radiation Safety Officer: ________________________________

Date Received: ________________________________________________
Introduction:

Ionizing radiation is known to cause harm in mammalian organisms. Deleterious effects of radiation include carcinogenicity, mutagenicity and organ system toxicity. As general rule, the sensitivity of a tissue to radiation is directly proportional to its rate of proliferation. Therefore, one could infer that the human fetus, because of its rapid progression from a single cell to a formed organism in nine months, is more sensitive to radiation than the adult. This inference is supported by the results of experiments in animal models, and experience with human populations that have been exposed to very high doses of radiation (atomic bombing victims).

In humans, the major deleterious effects on the fetus include miscarriage, teratogenicity (birth defects), mental retardation, intrauterine growth retardation and the induction of cancers (such as leukemia) that appear in childhood. Birth defects and mental retardation are the adverse effects which are of the most immediate concern for expectant mothers. Fortunately, not all exposures to ionizing radiation result in these outcomes.

The risk to the fetus is a function of gestational age at exposure and the radiation dose.

Those who work in or visit areas where nuclear substances are used need to understand the biological risks radiation presents to your unborn child.

Risk Related to Gestational Age

Early Gestation / First Trimester – At this point, the rate of fetal growth is very rapid and the fetus, as an organism, is at its most radiation-sensitive stage if fetal demise is taken as an end-point. The incidence of miscarriage consequential to radiation exposure at this stage of gestation is not known, since (a) many women were never aware they were pregnant at the time of the exposure or miscarriage, and (b) the "background" rate of miscarriage is believed to be high (25 - 50 percent of conceptions). It is believed that radiation injury during early gestation is an "all-or-nothing" effect.

Second Trimester – During this period, the overall growth rate of the fetus has slowed. However, the major organ systems are beginning to differentiate. From a standpoint of future development, the fetus is in its most sensitive stage. The incidence of gross congenital malformations and mental retardation are dose-related and appear to have thresholds; i.e. doses below which the incidence above "background" is not elevated.
Third Trimester – Irradiation during this period may deplete cell populations at very high doses (over 50 rem), but will not result in gross organ malformations.

**Risk Related to Radiation Dose**

The risk of deleterious effects increases with increasing dose. The nature of this dependence, i.e. the shapes of the dose-response curves for humans in the low-dose range (under 500 mSv), is controversial. For some prenatal irradiation effects, there is epidemiological basis for the existence of threshold doses. For others, such as childhood cancer induction, the existence of a threshold is not clear-cut. Despite these uncertainties in the dose-effect relationship, some broad generalizations based on fetal dose ranges may be made.

Fetal Dose less than 10mSv – There is no evidence supporting the increased incidence of any deleterious developmental effects on the fetus at diagnostic doses within this range.

Fetal Dose between 10mSv and 100mSv – The additional risk of gross congenital malformations, mental retardation, intrauterine growth retardation and childhood cancer is believed to be low compared to the baseline risk. However, the lower limits (in terms of statistical confidence intervals around the mean) for threshold doses in some studies, especially those related to cancer induction, fall within this range.

Fetal Dose Exceeding 100mSv – The lower limits (in terms of statistical confidence intervals) for threshold doses for effects such as mental retardation and diminished IQ and school performance fall within this range. Overall, exposure at levels exceeding 100mSv could be expected to result in a dose-related increased risk for deleterious effects. For example, the lower limit (95% confidence interval) for the threshold for mental retardation is about 150mSv, which an expectation value of about 300mSv.

**Legislative Requirements**

The International Commission on Radiological Protection (ICRP) regularly reviews the biological evidence of the detrimental effects of ionizing radiation and publishes appropriate recommendations regarding acceptably safe practices for the exposure of occupational workers, patients undergoing treatment/diagnosis, and for members of the public.

In Canada these recommendations have been incorporated into law in the Nuclear Safety and Control Act. The law is administered by the Canadian Nuclear Safety Commission. The Canadian Radiation Protection Regulations require that the dose to a pregnant NEW, after the licensee is informed of the pregnancy, shall not exceed 4 mSv.

**Responsibilities**

**Responsibility of female radiation workers**

As a NEW becomes aware of her pregnancy they shall immediately inform the RSO. The Declaration of Pregnancy Form must be completed and submitted to the RSO.
During pregnancy, the employee is expected to perform their duties within the restrictions applied by the RSO. The employee is encouraged to monitor her embryo/fetus dose by reviewing the personnel dosimeter reports and discuss these reports with the RSO.

**Radiation Safety Officer Responsibilities**

An assessment of the work situation shall be done to ensure that Radiation Safety Principles are being adhered to and that radiation dose limits are not exceeded and remain ALARA.

The RSO will review the workers previous dose history and current and/or planned work practice to determine the need for additional dosimetry.

Radiation exposures of pregnant NEW’s shall be monitored to ensure that the dose limit of 4 mSv for the balance of the pregnancy is not exceeded, in accordance with the Canadian Radiation Protection Regulations.

**References**


DECLARATION OF PREGNANCY FORM
Nuclear Substance Workers

I declare that I am pregnant, for the purposes of lowering the dose received by me and/or my embryo/fetus.

I understand and agree that additional monitoring may be required of me during the balance of my pregnancy to ensure that the dose limit of 4 mSv is not exceeded.

<table>
<thead>
<tr>
<th>Name of Worker (Print)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature of Worker</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Estimated Due Date</td>
<td></td>
</tr>
</tbody>
</table>

| Name of RSO (Print)             |   |
| Signature of RSO               |   |
| Date                            |   |
Title: Radiation Safety Training Policy

Number: RSP –D.3

Date: December 7, 2005; Revised April 2017

Introduction:

Section 12 (1)(b) of the CNSC “General Nuclear Safety and Control Regulations” require that every licensee shall:

“train the workers to carry on the licensed activity in accordance with the Act, the regulations made under the Act and the licence.”

Item 4 of the Dalhousie University, Nuclear Substance User Permit - Schedule of Conditions states:

“Principal Investigators (permit holders) are responsible for registering all persons under their supervision with the Radiation Safety Officer and ensuring that these persons are enrolled in the first available Radiation Safety Training Course offered by the university after that individual joins the lab.”

Training Procedure:

a) All new workers required to use/handle nuclear substances must be registered with the RSO within seven days of joining the research group. The PI must make an amendment to the permit on Environmental Health and Safety Assistant (ESHA) to add new workers. A Radiation Worker Registration form should also be submitted to the RSO. The form can be located on the EHS website.

b) The Principal Investigator (PI) shall ensure that all new workers read the Radiation Safety Training Manual, prior to the training session.

c) All new workers must register for the first available Radiation Safety Training course. Radiation Safety Training sessions will be scheduled five times annually. Schedules of available training sessions, as well as registration forms are posted annually to the EHS web site.

d) If it is required to have a person begin working with nuclear substances, prior to the next available training session, the RSO may approve the person to begin working. However, they must have read the Radiation Safety Training Manual, and are required to work under direct supervision of a trained, authorized radiation worker. The RSO must be informed of this situation by the PI.
e) Initial training is a one day workshop with practical hands on training. A grade of 75% is required to receive certification.

f) New workers may be exempted from participating in the training session at the RSO’s discretion. The RSO will determine if prior training is sufficient and equivalent to Dalhousie University’s training.

g) Worker re-training is required every 3 years. Radiation Safety Training and TDG Class 7 Receiving Radioactive Materials refresher slideshows and quizzes are available on the EH&S website. Refresher quizzes must be returned to the Radiation Safety Office to be marked. A grade of 80% or higher must be achieved to receive recertification.

h) The RSO will maintain all Radiation Safety Training records. All training records will be entered into the EHSA system by the RSO. Certificates of training completion will be issued and given to the PI to maintain with the laboratory records.

Responsibilities:

PI:
- To register new workers with the Radiation Safety Office within seven days
- To ensure their workers have read and understood the Radiation Safety Training Manual
- To ensure their new workers sign up for the next available Radiation Safety Training Course
- To maintain up to date training for both themselves and all lab workers
- To maintain records of all workers training
- To ensure untrained workers are working under direct supervision until next available training course

RSO:
- To hold training courses within a reasonable time frame
- To post current training dates and registration forms on the EHS website.
- To properly train workers using current information in Radiation Safety and TDG-Class 7 receiving
- To maintain the Radiation Safety Training Manual
- To maintain training records
Introduction:

The Canadian Nuclear Safety Commission (CNSC) has the mandate to regulate the use of nuclear energy and materials, in order to protect the health, safety, and security of Canadians and the environment. In carrying out this mandate, the CNSC is responsible for protecting the public and workers from exposure to ionizing radiation. A key way in which the CNSC fulfills its mandate is through the Radiation Protection Regulations, which sets radiation dose limits. In addition to ensuring that dose limits are respected, the CNSC requires radiation doses be kept as low as reasonably achievable (ALARA), with social and economic factors taken into account.

The CNSC licenses various activities that involve nuclear substances and radiation devices, and it monitors radiation doses that result from these licensed activities. The CNSC requires all licensees to ascertain and record doses assigned to anyone who performs duties associated with licensed activities. Licensees must make dose records available and report them to the CNSC.

Definitions:

**Dosimetry:** the act of measuring or estimating radiation doses and assigning those doses to individuals.

**External radiation exposure:** occurs when the radiation source or nuclear substance is outside of the body. Typically monitored by the use of small radiation detectors called dosimeters, which are worn on the person. At Dalhousie University, whole body badges and ring badges are worn to ascertain radiation exposures doses.

**Internal radiation exposure:** occurs when the radiation is emitted by nuclear substances inside the body. Typically monitored by measuring the presence of nuclear substances in the body, or by measuring nuclear substances excreted by the body. At Dalhousie University, thyroid monitoring and bioassays are performed using a thyroid uptake probe.

Dalhousie University monitors radiation exposure through personal dosimetry, via external and internal processes. External exposure to the trunk of the body is monitored using whole body radiation dosimeters and external exposure to the extremities is monitored by ring dosimeters. Internal radiation exposure is monitored using thyroid screening and bioassay techniques.
Individuals who handle nuclear substances specified by the Radiation Safety Officer (RSO), will be supplied a dosimeter. This procedure ensures radiation workers at Dalhousie University are following the ALARA program and working safely. In cases that action levels are exceeded, the RSO can take the necessary steps to reduce future exposure.

Individuals should refer to the CNSC poster “Proper Care and Use of Personal Dosimeters” for further information regarding how to handle, use and store your dosimeter.

Requirements:

1. The dosimeter must be worn when working with the nuclear substance or if there is a possibility of exposure.

2. If there is a possibility that effective doses of radiation exceed 5 mSv per year, personal dosimetry must be performed by a licensed dosimetry service. At Dalhousie University, the current dosimeter provider is Mirion Technologies.

3. Dosimeters are NOT required for individuals who work only with S-35, H-3 and/or C-14.

4. Radiation workers using radioiodines are required, under certain conditions, to have thyroid monitoring screening and/or bioassays. For further information regarding thyroid monitoring refer to the Thyroid Monitoring, Screening and Bioassay policy.

5. The RSO is required to report to the CNSC any occupational exposure levels that exceed the CNSC’s prescribed dose limits.

6. Post the CNSC information poster; Proper Care and Use of Personal Dosimeters, within the laboratory.

Procedure:

1. Principle Investigators (PI) must request dosimeters from the RSO for new personnel by completing the Radiation Worker Registration Form. Only individuals directly working with the detectable nuclear substances are required to have a dosimeter. All pertinent information will be reviewed and the RSO will issue dosimeters based on the type and quantity of isotopes being handled.

2. Dosimeters are exchanged on a quarterly basis and sent back to the service provider to be analyzed. Workers must ensure to submit the badges when requested for analysis. Once the old badge is surrendered, the new badge will be distributed. If a dosimeter is lost or damaged it will be the Department’s responsibility to cover the cost of a replacement.

3. Pregnant radiation workers may be issued a second dosimeter to wear, which will be exchanged on a monthly basis. This allows for a quicker response to possible radiation exposure and will allow corrective measure to be put into place in a timely fashion, avoiding unnecessary radiation exposure to the embryo/fetus.
4. The quarterly Occupational Exposure Report is issued to the RSO. The RSO will review all results and inform any radiation worker if they have exceeded any action levels. This may also warrant an investigation of probable causes for the exposure and preventative measure to prevent future exposure.

5. The quarterly Occupational Exposure Report will be sent to each location utilizing dosimeters. It is also the responsibility of each worker to review their individual occupational exposure results and know the dose limits for their radiation worker classification. Refer to the ALARA Policy for action levels and radiation dose limits.

6. The RSO will maintain all Occupation Radiation Exposure Reports.

7. The RSO is required to report to the CNSC any radiation worker who has exceeded the CNSC dose limits. The RSO must submit a written report within 21 days of the discovered occurrence.

Responsibilities:

PI:
- To request dosimeters for necessary workers
- To ensure you and your workers wear your dosimeter correctly and when necessary
- To ensure timely exchange of badges for you and your workers
- If applicable, to post the CNSC poster “Proper Care and Use of Personal Dosimeters”

Radiation Workers:
- To ensure you wear your dosimeter correctly and when necessary
- To ensure timely exchange of badges for you and your workers

RSO:
- To review all dosimeter readings
- To alert readings over Dalhousie University’s action levels with the individual and discuss why action levels were reached and how to prevent this in the future
- To report readings over CNSC action levels to the CNSC within 21 days
- To send and collect dosimeters from the distributors
- To retain all records of dosimeter readings
Title: Thyroid Monitoring, Screening and Bioassay Policy

Number: RSP – D.4.1

Date: December 1983, March 2017

Thyroid screening of nuclear substance workers who handle volatile radioiodine is required by licence conditions. The purpose of a thyroid screening program is to monitor the intake of volatile radioiodine. Timely information produced by the program is used to assess any intake of volatile radioiodine, provide assurance that the radiation protection program is working, and demonstrate compliance with regulatory dose limits (RD-58).

The Nuclear Substance and Radiation Devices licence conditions state:

**Licence Condition 2046-17: Thyroid Monitoring**

a) Every person who in any 24-hour period uses a total quantity of Iodine-124, Iodine-125, or Iodine-131 exceeding:
   i. 2 MBq in an open room;
   ii. 200 MBq in a fume hood;
   iii. 20,000 MBq in a glove box; or
   iv. any approved quantity in any room, area or enclosure authorized in writing by the CNSC shall undergo thyroid screening within a period more than 24 hours after the last use that resulted in any of the above limits being exceeded, and less than 5 days after the limit was exceeded.

b) Every person who in any 24-hour period uses a total quantity of Iodine-123 exceeding:
   i. 200 MBq in an open room;
   ii. 20,000 MBq in a fume hood;
   iii. 2,000,000 MBq in a glove box; or
   iv. any approved quantity in any room, area or enclosure authorized in writing by the CNSC shall undergo thyroid screening within a period more than 8 hours after the last use that resulted in any of the above limits being exceeded, and less than 48 hours after the limit was exceeded.

c) Every person who is involved in a spill greater than 2 MBq of Iodine-124, Iodine-125, or Iodine-131, or on whom external contamination is detected, shall undergo thyroid screening within a period more than 24 hours after the spill and less than 5 days after the spill or contamination.

d) Every person who is involved in a spill of greater than 200 MBq of Iodine-123, or on whom external contamination is detected, shall undergo thyroid screening...
within a period more than 8 hours after the spill, and less than 48 hours after the spill or contamination.

**Licence Condition 2600-4: Thyroid Screening**

Screening for internal Iodine-123, Iodine-124, Iodine-125 and Iodine-131 shall be performed using:

a) Direct measurement of the thyroid with an instrument that can detect 1 kBq of Iodine-124, Iodine-125 or Iodine-131, or 10 kBq of Iodine-123; or

b) Bioassay procedure approved by the Commission or a person authorized by the Commission.

**Licence Condition 2601-7: Thyroid Bioassay**

a) If thyroid screening detects more than 10 kBq of Iodine-124, Iodine-125, Iodine-131, or 100kBq of Iodine-123 in the thyroid, the licensee shall immediately make a preliminary report to the Commission or a person authorized by the Commission, and have bioassay performed within 24 hours by a person approved by the Commission to provide internal dosimetry.

**Procedure:**

1. The Radiation Safety Officer (RSO) *shall* be notified **24 hours in advance** of any procedure involving radioiodine that meet or exceed the conditions as described in condition #2046-17 of the licence.
2. The RSO *shall* be notified immediately of any spill or external personal contamination with any amount of radioiodine.
3. If any of the conditions from #2046-17 are met or exceeded, arrangements will be made to have thyroid screening performed within the appropriate time frame. Thyroid screening will be coordinated by the RSO. Based on the initial thyroid screening measurements, further testing may be required. This will be determined by the RSO, who will provide further direction, if required.
4. Workers must adhere to the Radioiodine Conditions listed on the Nuclear Substance User Permit.
Title: Sealed Source Leak Testing Policy

Number: RSP – D.8

Date: March 2017

Introduction:

Under the Nuclear Substances and Radiation Devices Regulations, the CNSC require that particular sealed sources be tested to ensure that the protective covering has not developed defects, been damaged, or has degraded, so as to present an unrecognized radiological risk to persons using or working near the source. If a sealed source exceeds the regulatory contamination limit, corrective actions must be taken immediately. Leak testing requirements are outlined in the CNSC document *Nuclear Substances and Radiation Devices Regulations*, under section 18.

Requirements for ALL Sealed Sources:

All sealed sources are to be registered with the Radiation Safety Officer (RSO). All documentation must be provided with registration to include information such as the radioisotope, original activity, reference date or assay date, manufacturer, model number, serial numbers, etc. If a certificate of compliance is provided with the source at the time of purchase, a copy of the certificate should be submitted upon registration. Each registered sealed source will be assigned a number which will be used to identify the sealed source for inventory purposes. This number must be affixed to the sealed source at all times.

All sealed sources in possession over 50 MBq are required to be leak tested based on the following criteria from the Nuclear Substance and Radiation Devices Regulations:

Frequency of leak tests:

(a) where the sealed source or shielding is used after being stored for 12 or more consecutive months, immediately before using it;

(b) where the sealed source or shielding is being stored, every 24 months;

(c) where an event that may have damaged the sealed source or shielding has occurred, immediately after the event; and

(d) in all other cases:

   (i) where the sealed source or shielding is located in a radiation device, every 12 months, and
(ii) where the sealed source or shielding is not located in a radiation device, every six months.

The RSO will manage the leak testing schedule. Principle Investigators (PI) will be notified of leak testing if they are in possession of regulated sealed sources. Leak testing kits and testing directions will be distributed to the appropriate person. The RSO will make arrangements with a CNSC approved service to perform the analysis. All leak testing records will be kept by the RSO. If the individual wishes to receive a copy of the leak test results, please contact the RSO. The RSO will notify only those individuals whom have test results in excess of 200 Bq.

In the result of a leakage of 200Bq or more:

- Use of the source must be discontinued and put in storage.
- Use of the device that the source is located in must be discontinued and put in storage.
- Measures must be taken to limit the spread of radioactive contamination.
- The CNSC must be notified immediately after discontinuing use and managing the spread of contamination.

Wipe Sampling Procedure:

1. Use the cotton swabs provided in the test kit to perform the sample wipes. The first swab is for a background measurement. The second swab is for the source leak test.
2. If you have more than one source to test, you will receive multiple test kits. Only one test kit may be used per source.
3. Lightly moisten the wipe with alcohol or water.
4. Using uniform and constant pressure, ensure the area is wiped as appropriate for the source. Roll the swab to ensure all swab surfaces have come into contact with the source or housing, as appropriate.
5. Carefully allow the wipe to dry preventing any loss of activity. Do not touch the wipe or allow it to come into contact with other objects to prevent potential contamination spread.
6. Put the cotton swab back into the holder of test kit when dry.
7. Complete the remainder of the information on the test kit certificate. This would include the date of test completion and the sampler's name. All other required information on the test certificate will be completed by the RSO prior to distribution.
8. Promptly return the test kit(s) to the RSO on the requested date.

Expectations for Sampling:

Sampling must be performed by a qualified person working with nuclear substances. They must be a trained radiation safety worker or deemed qualified by the RSO to perform the leak testing. In each case, the RSO will designate an appropriate individual to perform the leak testing, will oversee the leak testing with the individual, or will conduct the test themselves.

Responsibilities:

PI:
- To register any sealed source with the RSO.
- To ensure that the leak test is completed according to the provided procedures.
To return the wipe test to the RSO in the time frame requested.
To inform the RSO immediately if they, or a worker in their lab, become aware that a sealed source is leaking, has been damaged or potentially damaged.

**RSO:**
- To distribute wipe test kits to the PI's and ensure that the leak test procedures are provided.
- To return the samples to the vendor in a timely manner.
- To alert and discuss leak test results of 200Bq or more with the applicable PI.
- To report leak tests in excess of 200Bq to the CNSC in a timely manner.
- To maintain records of all the leak test results.
Introduction:

Ensuring the security of nuclear substances consists of two components:

   a) Accountability
   b) Physical security

Access of nuclear substances is to be controlled from the time of acquisition until transfer or disposal. Individuals working with nuclear substance are accountable for the security of those substance. Records of use of nuclear substances shall be kept up to date and accurate. When nuclear substances are not in use or not under the direct supervision and control of an authorized person, they and/or radiation devices should be kept in a locked area, room, enclosure or vehicle.

These components are put in place to reflect the regulatory requirements outlined by the Canadian Nuclear Safety Commission (CNSC) and to ensure the safety of individuals at Dalhousie University.

The Canadian Nuclear Safety Commission further requires under its “General Nuclear Safety and Control Regulations” that:

a) Section 12: Obligations of Licensees

   g) implement measures for altering the licensee to the illegal use or removal of a nuclear substance, prescribed substance, prescribed equipment or prescribed information, or the illegal use of a nuclear facility

   h) implement measures for alerting the licensee to acts of sabotage or attempted sabotage anywhere at the site of the licenced activity;

   j) instruct workers on the physical security program at the site of the licenced activity and on their obligations under that program;

b) Section 17: Obligations of Workers

   c) promptly inform the licensee or the worker’s supervisor of any situation in which the worker believes there may be:
i. a threat to the maintenance of security or an incident with respect to security
ii. an act of sabotage, theft, loss or illegal use or possession of a nuclear substance, prescribed equipment or prescribed information

Requirements:

a) Only authorized workers, individuals who are certified by the Radiation Safety Officer (RSO), may have access to nuclear substances. Access to nuclear substances should be limited in such a manner that an individual with authorized access to the area, but who is not authorized to use or possess the materials, cannot gain control of the materials.

b) When nuclear substances are not in use, for any period of time, it must be secured in a locked container, room, enclosure or vehicle. For clarification or consultation on appropriate locking mechanisms, contact the RSO.

c) Constant surveillance and control must be maintained for nuclear substances in use. If at any time an authorized worker is unable to supervise the laboratory must be locked or the nuclear substance must be secured.

d) When receiving a nuclear substance it must be properly secured upon delivery. For more information of receiving protocol please review the Receiving of Nuclear Substances and Radiation Devices policy.

e) If a nuclear substance is in storage it must be contained in an appropriate container that is locked.

f) Radioactive waste containers must be secure from unauthorized removal.

g) Storage of nuclear substances in hallways is not permitted.

Loss or Theft:

a) The authorized workers must comply with the proper security measures outlined above, including locking nuclear substances in laboratories, containers, fridges, or vehicles, to prevent loss or theft of nuclear substances.

b) If a worker becomes aware that a nuclear substance has been tampered with, lost or stolen they must immediately report the incident to the RSO. The RSO can be contacted by phone (ext.1938) or email, which can be located on the Environmental Health and Safety website.

c) The RSO must report the incident to the CNSC within 21 days of the occurrence.

Responsibilities:

a) It is the responsibility of the Principle Investigator (PI) to secure nuclear substances in their possession from unauthorized access or removal.
b) It is the responsibility of the PI or his/her designate to maintain surveillance over nuclear substances while in use.

c) The PI is responsible for the security of the nuclear substances from the time of acquisition until the time of disposal or transfer.

d) If constant surveillance cannot be maintained, the materials must be secured in a locked container.

e) Nuclear substances must be secured in such a manner that an individual with authorized access to the area, but who is not authorized to use or possess the materials, cannot gain control of the materials.

f) The PI or his/her designate must contact the RSO immediately if any actual or suspected loss or theft of a nuclear substance.

g) The RSO must report loss or theft to the CNSC within 21 days.
**Title:** Transfer of Nuclear Substances and Radiation Devices  
**Number:** RSP – D.10  
**Date:** December 7, 2005; Revised April 2017

**Introduction:**


The Dalhousie University license permits the transfer of nuclear substances and/or radiation devices both internally within the university and externally to other nuclear substance licencees.

All internal and external transfers of nuclear substances and radiation devices at Dalhousie University must be approved by the Radiation Safety Officer (RSO) before any transfer takes place. All internal transfers will require the completion of the Internal Transfer of Nuclear Substances form. The RSO will confirm and coordinate the type of transfer required, ensure all parties are licenced to accept the transfer, update the inventory for the transfer and provide further guidance for all transfers. Transfers are to take place during normal working hours only.

**Procedure:**

**Internal Transfers:**

1. Transfers from one permit holder to another within the same department are permitted by completing the Internal Transfer of Nuclear Substances form. Both parties must complete the Internal Transfer of Nuclear Substances form and submit it to the RSO for approval. Once approved, the RSO will process the transfer in EHSA system and send a signed copy of the transfer form to both parties to retain as documentation of the transfer. After receiving the signed form from the RSO, the physical transfer may occur.

2. Transfers from one permit holder to another in different departments or different physical locations on campus are permitted, provided the material falls below the category “Radioactive Material-Exception Package-Limited Quantity of Material”. Both parties must complete the Internal Transfer of Nuclear Substances form and submit it to the RSO for approval. Once approved, the RSO will process the transfer in EHSA system and send a signed copy of the transfer form to both parties to retain as documentation of the transfer. After receiving the signed form from the RSO, the physical transfer may occur.
3. If the nuclear substance to be transferred internally meets the minimum requirements for a “Radioactive Material-Excepted Package-Limited Quantity of Material” or greater, then it must be packaged and transported according to the Packaging and Transport of Nuclear Substances Regulations, 2015 (PTNSR 2015). Both parties must complete the Internal Transfer of Nuclear Substances form and submit it to the RSO for approval. Once approved, the RSO will process the transfer in EHSA system and send a signed copy of the transfer form to both parties to retain as documentation of the transfer. After receiving the signed form from the RSO, the physical transfer may occur. If the permit holder is not certified to ship Class 7 radioactive packages, they will not be able to perform this function. See Packaging and Transport of Nuclear Substances Policy, for further direction.

**External Transfers:**

1. Transfers of nuclear substances or radiation devices to external institutions or licencees are only to take place with the authorization and coordination of the RSO. The RSO will ensure the recipient licencee is eligible for the transfer, according to the CNSC licence. If the nuclear substance to be transferred externally does not fall below the requirements of a Radioactive Material-Excepted Package-Limited Quantity of Material package, then it must be packaged and transported according to the Packaging and Transport of Nuclear Substances Regulations, 2015 (PTNSR 2015). This will require certification for Shipping Class 7 Radioactive Packages. See Packaging and Transport of Nuclear Substances Policy, for further direction.

2. Transfers of nuclear substances or radiation devices to Dalhousie University from an external institution or licensee, must be authorized and coordinated by the RSO to ensure Dalhousie University is eligible for the transfer. Contact the RSO for further direction.

3. Transfers of any sealed sources meeting the requirements of a Category 1, 2 or 3 sealed source under REGDOC 2.12.3 Security of Nuclear Substances: Sealed Sources, will be transferred using the Sealed Source Tracking System (SSTS). Dalhousie University is registered with the SSTS. All external transfers will be reported using the SSTS at least 7 days in advance of the transfer and within 48 hours of any reception of a transfer. All requirements of the Packaging and Transport of Nuclear Substances Regulations, 2015 (PTNSR 2015) will be met to ship and receive a Category 1, 2 or 3 sealed source.
Internal Transfer of Nuclear Substances

All parties must complete the form below and then submit it to the RSO. The physical transfer of the isotope can only occur AFTER the RSO has approved the transfer and has returned a signed copy to all parties. Each party MUST retain a copy of the form signed by the RSO in their records book.

Principal Investigator: ____________________________

Permit #: ____________________________

Inventory #: ____________________________

Radioisotope: ____________________________

Quantity (volume & activity): ____________________________

Form: Solid ___ Liquid ___ Gas ___

Sealed Source: Device Model: __________ Serial Number __________ RS # ______

From: Room # ______ Building ________

To: Room # ______ Building ________

Requested Date of Transfer: ____________________________

Supplier (Principal Investigator):

__________________________________________
Name ____________________________ Signature ____________________________ Date

Shipper:

__________________________________________
Name ____________________________ Signature ____________________________ Date

Recipient:

__________________________________________
Name ____________________________ Signature ____________________________ Date

RSO Approval:

__________________________________________
Name ____________________________ Signature ____________________________ Date

New Inventory #: ____________________________
External Transfer of Nuclear Substances

Dalhousie University Information:

Principal Investigator: ______________________________________
Permit #: _________________________________________________
Inventory #: ______________________________________________
Radioisotope: ______________________________________________
Quantity (volume & activity): __________________________________
Form: Solid ___ Liquid ___ Gas ___
Sealed Source: Device Model: __________________ Serial Number ______ RS # ______

Receiving Facility Information:

Recipient Name: __________________ CNSC Licence #: _____________
Recipient Address: __________________________________________
Name and Address of Destination: __________________________________
Requested Date of Transfer: __________________________________

Supplier (Principal Investigator):

________________________ Name _______________ Signature __________ Date

Shipper:

________________________ Name _______________ Signature __________ Date

Recipient:

________________________ Name _______________ Signature __________ Date

Dalhousie University RSO Approval:

________________________ Name _______________ Signature __________ Date

Verification of Safe Arrival (initial): ____
Title: Packaging and Transport of Nuclear Substances and Radiation Devices

Number: RSP – D.11.1

Date: April 2017

Introduction:

The Canadian Nuclear Safety Commission (CNSC) issues licences and certificates for certain kinds of packaging and transport of nuclear substances as stipulated in the Packaging and Transport of Nuclear Substances Regulations, 2015 (PTNSR 2015). These regulations are based on the International Atomic Energy Agency’s (IAEA) Regulations for the Safe Transport of Radioactive Material, 2012 Edition. The Regulatory requirements for packaging and transport in Transport Canada’s Transportation of Dangerous Goods Regulations (TDGR) are also followed. These regulatory documents have very specific procedures for each type of package and the details of each transport.

All nuclear substances are transported in packages that are selected based on the nature, form, and quantity or activity of the substance. There are general design requirements that apply to all package types to ensure that they can be handled safely and easily, secured properly, and are able to withstand routine transport conditions. To be certified by CNSC, packages must meet stringent performance criteria for shielding, containment, ability to withstand impacts, ability to withstand heat, and more.

The Dalhousie University CNSC license permits the transfer of nuclear substances and/or radiation devices both internally within the university and externally to other nuclear substance licensees. Transfer of isotopes at Dalhousie University generally fall into the categories of Excepted packages or Type A packages.

Requirements:

According to the Packaging and Transport of Nuclear Substances Regulations, 2015 (PTNSR 2015), section 42 (1) states:

Every person who packs radioactive material in a Type A package must keep a record documenting the following information regarding the package:

a) the technical specifications of its design
b) the type, quantity and physical state of the radioactive material that it is designed to contain
c) any document that demonstrates that the package meets the requirements of the Regulations and the management system
d) instructions for packing, transport, receiving, maintenance and unpacking

All documentation must be maintained as part of the records. All records must be maintained until authorized by the Radiation Safety Officer (RSO) to discard.
All transfers of nuclear substances and/or radiation devices must be coordinated by the RSO. See Transfers of Nuclear Substances and Radiation Devices Policy for further information on transfers.

Training requirements:

All persons preparing radioactive material for transport must have appropriate training in ground or air transport and a current Transport of Dangerous Goods Certificate. This training is NOT offered at Dalhousie University. Training must be taken from an external source. Training and re-training is the responsibility of the researcher. Copies of the training certificate shall be provided to the RSO, as well as maintained within the laboratory.

Procedure:

Packaging of Radioactive Material

The following information is a guide and does not replace the specific requirements of transport of dangerous goods regulations. All persons, packaging and shipping radioactive material must follow all regulatory requirements.

1. Material is shipped as “Excepted Radioactive Material” if:
   
   a) The non-fixed activity for beta and gamma emitters, as measured by a wipe test of the primary container and the exterior package (6 sides), demonstrates an activity less than 4 Bq/cm² measured over 300 cm².
   b) The exposure reading at the surface of the package is less than 5 μSv/hr
   c) The word “radioactive” is clearly visible to anyone opening the package.
   d) The radioactivity does not exceed the cut-off activity as indicated in the regulations.
   e) The shipping documents bear the words “Radioactive Material - Excepted Package”
   f) Documentation travelling with the package lists:

   - Radionuclide
   - Activity
   - Results of wipe test (demonstrating compliance with regulations)
   - Exposure reading at package surface (demonstrating compliance)
   - Form of radionuclide (solid, liquid, gas)
   - Shipping department including licence or permit number.
   - Receiving department including licence or permit number.
   - Signature of sender and date.

2. Material is shipped as a “Type A package” if:
   
   a) It does not meet the criteria for an excepted package.
   b) The non-fixed activity for beta and gamma emitters, as measured by a wipe test of the primary container and the exterior package (6 sides), demonstrates an activity less than 4 Bq/cm² measured over 300 cm².
   c) The appropriate radioactive labels are present on two opposite sides of the package.
   d) The shipping documents bear the words “Type A - Package”
   e) Documentation travelling with the package lists:

   - Radionuclide
   - Activity
• Results of wipe test (demonstrating compliance with regulations)
• Exposure reading at package surface (demonstrating compliance)
• Form of radionuclide (solid, liquid, gas)
• Shipping department including licence or permit number.
• Receiving department including licence or permit number.
• Signature of sender and date.

f) A Bill of Lading for Transport of Dangerous Goods must also accompany the package.

g) Type A packages must be categorized by the radiation level and have appropriate labels:

• **Category I – White:** Does not exceed 5 μSv/hr at any location on the external surface of the package.
• **Category II – Yellow:** Does not exceed 500 μSv/hr 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/hr at any location on the external surface of the package and the transport index does not exceed 10.

h) The Transport Index (TI) for a package is the maximum radiation level in μSv/hr at one meter from the external surface of the package, divided by 10.

   Example: 1 μSv/hr at 1 m = TI of 0.1
Introduction:

The regulatory requirements for the packaging and transport of nuclear substances and radiation devices in Canada are specified in the Packaging and Transport of Nuclear Substances Regulations, 2015 and Transport Canada’s Transportation of Dangerous Goods Regulations (TDGR). Specific procedures for handling radioactive packages are described in the Canadian Nuclear Safety Commission (CNSC) INFO Document “Guidelines For Handing Packages Containing Nuclear Substances, INFO - 0744”

Procedures for receiving radioactive material should be established to ensure the material is:
- delivered to the user without delay, or securely stored until delivery.
- immediately inspected for evidence of leakage, damage, or tampering.
- only opened by personnel authorized to do so.
- properly stored after receiving.

Definitions:

**Excepted Package:**
This package type is used to transport small quantities of radioactive materials. No radioactive labeling is required on the exterior of the package however, upon opening the package the safety mark “radioactive” must be visible. The radiation level at any point on the external surface of the package must not exceed 5µSv/h.

**Type A Package:**
There are three categories of **Type A packages**:
- **Category I – White:** The radiation level at the package surface is less than or equal to 5µSv/h and the transport index is 0.
- **Category II – Yellow:** The radiation level does not exceed 500µSv/h at any location on the external surface of the package and the transport index doesn’t exceed 1.
- **Category III – Yellow:** The radiation level does not exceed 2mSv/h at any location on the external surface of the package and the transport does not exceed 10.

**Consignor:** The person responsible for shipping the package

**Consignee:** The recipient of the shipment/package

Receiving a Package:

All radioactive material received should be designated for an authorized licence or permit holder. Upon purchasing nuclear substances, the university licence will be supplied to the vendor,
verifying possession limits and authorized locations for delivery. The address label should provide sufficient information for the delivering company to accurately locate the individual or department responsible for the package.

Receiving procedures are used as a method to monitor the integrity of the package. A small percentage of incoming packages are leaking or contaminated. The consignor is responsible to follow all regulatory requirements for the packing and transport of nuclear substances and therefore becomes a part of the reporting process. The reporting mechanism identifies companies with poor track records for packaging and transport.

The CNSC guidelines “Guidelines For Handling Packages Containing Nuclear Substances, INFO - 0744” should be posted at the location where the package is opened.

The process of receiving a radioactive package at Dalhousie University requires the radiation worker to have completed the Radiation Safety Training conducted by the Radiation Safety Officer (RSO). Completion of the course will certify Dalhousie University radiation workers in general radiation safety, as well as Receiving Class 7 Radioactive Packages. Only trained, authorized radiation workers shall receive a radioactive package. This course does NOT provide certification for shipping radioactive packages. Re-training for Class 7 Receiving is required every 3 years. Contact the RSO for further training information.

Deliveries should be scheduled to take place during normal working hours. Upon receipt, unopened packages of radioactive material should be promptly delivered to the recipient by placing them on a cart or other device to increase the distance between people and the package, in order to minimize radiation exposure. If the radioactive package is delivered during off-duty hours, deliveries should be stored in a specified location that is secure and prevents unnecessary exposure to the general public.

Procedure:

When Opening a package of UNSEALED nuclear substances, take the following precautions:

A) Wear protective clothing while handling the package (lab coat, gloves).
B) Wear issued personal dosimeters (whole body and or ring badges).
C) If the material is volatile (unbound iodine, tritium, radioactive gasses etc.) or in powder form, open the package in a fume hood.
D) Open a shipment behind proper shielding, if applicable.

Upon receipt of a nuclear substance package the Consignee must:

A) Ensure packages are never left unsecured.
B) Inspect the package carefully. The initial inspection should verify the address on the delivery label. Any package that does not have the address should not be accepted. Once a package is accepted, even if it does not belong at the university, it becomes the responsibility of the consignee/University/RSO.
C) Inspect for leaks or damage. If the package is leaking or damaged, contain the package and isolate it to minimize radiation exposure and contamination. Proceed with decontamination procedures, if necessary. Contact the RSO.
D) Ensure all packing slips and shipping declarations are with the package. These documents must be maintained for record keeping within the lab.
E) Avoid unnecessary direct contact with unshielded containers.
Opening a Package:

A) If an appropriate survey meter is available, monitor the radiation field around the package and compare with the units stated on the package. Note any discrepancies.
B) Wipe test the exterior of the package for removable surface contamination.
C) Open the outer package and check for possible damage to the contents, broken seals, or discoloration of packing materials. Wipe test the interior packaging.
D) Wipe test the following: the inner packaging, primary container external and internal, and wipe test the stock vial.
E) Verify the radioisotope, activity, and other details using the information on the packing slip and the purchase order.
F) Log the radioisotope, activity, date received and any anomalies in the Environmental Health and Safety Assistant (EHSA) inventory record.
G) Report any anomalies (contamination, leakage, wrong activity, radiation levels in excess of package labelling or wrong shipment) immediately to the Principle Investigator or RSO for reporting to the CNSC.
H) If the packaging is free of contamination, remove or deface all radiation warning symbols or text before discarding. Discard contaminated waste as per Management of Radioactive Waste Policy.
I) Secure the stock vial in a locked area.

Reporting Requirements:

Any person that receives a package should inspect the integrity of the package and report any of the following conditions to the RSO immediately upon discovery:

A) Incorrect package label
B) Damaged package
C) Leakage
D) Packages with evidence of being tampered with
E) Any radiation levels above regulatory limits
F) Lost or stolen shipments

As per section 40 (4) of the Packaging and Transport of Nuclear Substance Regulations 2015, if any of the above conditions exist, an immediately preliminary report must be made to the CNSC and to the consignor. Contact the RSO for further direction. As per section 40 (6) of the Packaging and Transport of Nuclear Substances Regulations 2015, a full written report will be submitted to the CNSC within 21 days.

Record Keeping:

A) All receiving records and shipping documents must be maintained unless authorized to dispose of the records by the RSO. Keep all shipping documents. All information regarding the receipt of the nuclear substance is to be entered into the EHSA system.
B) Training certificates are issued by the RSO upon completion of the Radiation Safety Training course. All training certificates are to be maintained by the individual laboratories. Training certificates need to be presented upon request by the compliance inspectors at any time. The RSO will also maintain training certification records within the EHSA system.
Title: Controlling Possession of Nuclear Substances
Number: RSP – D.12.1
Date: April 2017

Introduction:

It is a requirement of the Canadian Nuclear Safety Commission (CNSC) to be able to account for all nuclear substances and radiation devices from the time they are acquired, until the time they are transferred or disposed. Management of the inventory is critical to maintain control of the licence. Non-compliance may lead to the CNSC revoking the licence, which means that Dalhousie University will not be permitted to work with nuclear substances and radiation devices. Dalhousie University maintains control of the nuclear substance inventory through a number of processes, as described below.

Processes:

1. All purchases of nuclear substances and radiation devices must be approved and authorized by the Radiation Safety Officer (RSO). The RSO must review the CNSC licence and the requesting Principle Investigator’s (PI) internal permit for the requested isotopes and possession limits. All nuclear substance inventory acquired by Dalhousie University is managed with an electronic database called the Environmental Health and Safety Assistant (EHSA). The EHSA contains all of the license information, such as isotopes and possession limits. Upon adding a purchase order entry into the system, the system shows the total university inventory held, as well as the total inventory of the PI. It then determines if any of the possession limits are exceeded, either for the licence or the PI. This allows the RSO to ensure the licence possession limits and the permit limits are not exceeded at any time. If the PI is over the possession limit with the new request, the order will not be placed by the RSO. The PI will be notified of the reason the order is not placed and suggestions made, if possible, how to correct the situation. In these situations, an amendment may be made to the internal permit or the CNSC licence to accommodate the request for isotope use.

Once approved by the RSO, purchases are processed through the Procurement Office. Procurement ensures that nuclear substance orders are approved by the RSO and will then issue a copy of the CNSC licence to the supplier, if required. The licence contains all of the locations that are allowed to accept the transfer of nuclear substances for Dalhousie University. Any orders that are not authorized by the RSO would be flagged by the supplier, as they would not have a copy of the licence showing the allowable locations with complete addresses for the possession nuclear substances.

2. It is required that all sources of nuclear substance be entered in the EHSA. All inventory, usage and disposal is maintained and recorded. Sealed sources, devices, and equipment inventories are also maintained by the EHSA. All relevant information is to be entered into the permit application by the PI. Daily usage will be recorded by the radiation workers. The RSO will update and maintain the inventories with respect to sealed sources with the notification of
transfers and or disposals. The RSO will also dispose of all nuclear substance waste, which is contained within the EHSA. Therefore all records will be maintained within the EHSA.

3. All laboratories are required to self-inspect, twice per calendar year. During this process, all inventory is to be verified, including open sources, sealed sources and/or radiation devices. During inspections conducted by the RSO, the PI’s will be asked to verify their inventory by confirming the possession of all items entered within the EHSA and signing the report generated from EHSA.

All sealed sources and radiation devices must be registered with the RSO and will be assigned a number. The RSO will conduct an annual inspection of all registered sealed sources. Each sealed source will be physically identified and accounted for.

4. Access to all nuclear substances and radiation devices is limited to trained radiation workers. All radiation workers receive the appropriate training to work with nuclear substances and are trained to have nuclear substances secured at all times. All nuclear substance laboratories must be locked without the presence of an authorized radiation worker. All nuclear substances stored in fridges, freezers, lock boxes, or special containers must contain a locking mechanism and be secured from removal by unauthorized personnel.

5. All waste is disposed by the RSO. The PI is responsible to close the waste containers within the EHSA system and contact the RSO for a waste drop off. Most waste is held in a delay and decay program, managed by the RSO. The RSO is responsible to transfer the waste in EHSA to the appropriate area, and document the final disposal methods and other pertinent information. All waste records are maintained in the EHSA system.

6. All parties involved in a transfer must maintain all appropriate documentation. Upon request of a transfer to the RSO, the RSO will oversee the process, ensuring all procedures are followed. This would include updating the inventory in the EHSA.
Title: Purchasing Policy

Number: RSP – D.12.2

Date: October 1997, reviewed 12/05, April 2017

Introduction:

All purchases are monitored and reviewed by the Radiation Safety Officer (RSO) to ensure that the University and Principle Investigator’s (PI) remain within the Canadian Nuclear Safety Commission (CNSC) regulations and in compliance with our overall license possession limits.

This policy is in place to minimize fraudulent possessions of nuclear substances.

Responsibilities:

PI:

- Verification of the material requested to be purchased is allowed as per the conditions of their permit
- Complete the purchasing requisition and forward it to the RSO

RSO:

- To oversee the nuclear substance purchasing process at Dalhousie University
- Review and approve or deny purchases
- Forward the approved requisitions to the Procurement Office

Purchase Procedure:

1. Purchase requisitions are to be completed by the PI and sent to the RSO by fax [(902) 423-5242] or email for approval, prior to the order for the material being placed.

2. The PI shall verify that the nuclear substance is allowed on their internal permit, if it is not, an amendment is required to first be submitted in the Environmental Health and Safety Assistant (ESHA) program.

3. The RSO will enter the requested purchase into EHSA to review PI’s current inventory as well as the total inventory for Dalhousie University, to ensure the licence permits the requested isotope and the possession limits are not exceeded.

4. Once the order is verified, if acceptable, the RSO will forward the approved requisition to the Procurement Office. RSO will notify in the case where the requisition is not approved.
5. The requisition shall include the product number, nuclear substance ordered, and activity required. The delivery address must be correct, and must align with the address listed on the current licence. An improper address will not be delivered as per CNSC regulations. Orders for a nuclear substance not listed on an individual permit will not be approved.

6. All orders for radioactive materials are required to be placed by the Purchasing Department. **Employees shall not purchase radioactive materials using their P-card.** Please see the *Compliance Enforcement Policy* for further information on the repercussions of incorrect purchasing procedures.

7. Approved requisitions can be viewed on Environmental Health and Safety Assistant (ESHA) program and will also appear in the online inventory for receiving the radioactive package.
Title: Radiation Emergency Procedures Policy
Number: RSP – D.14
Date: Initial March 2017

Introduction:

This procedure provides guidance with respect to accidental exposure to radioactive material. This includes, but is not limited to, a spill of radioactive liquid, intake of radioactive material by ingestion, inhalation, injection or entry through a cut or wound, or an external source of unwanted irradiation such as an X-ray machine or radioactive sealed source.

Any Radiation Users or Nuclear Energy Workers who know or suspect that they or anyone else, have been involved in any abnormal situation as described above should immediately report the fact with as much detail as possible to the Permit Holder. If skin, clothing, or shoes may be contaminated, it is preferable to remain on the spot (moving away from the immediate area of contamination) and to call for assistance. In this way the spread of contamination to other rooms is prevented.

All incidents involving abnormal exposure and/or contamination must be reported to Radiation Safety Officer (RSO) at the Environmental Health & Safety Office, as soon as possible.

Radiation Safety Officer will:

- Assist in facilitating the emergency response;
- Estimate the radiation dose(s) received by the person(s) involved. This may necessitate the immediate read-out of personnel (TLD) dosimeters and/or the provision of special bioassay procedures for the individual(s) concerned;
- Advise on the necessity, or otherwise, of medical examination and arrange such examination if appropriate; investigate the incident with a view to determining its cause and advising on remedial measures to prevent a recurrence;
- Assist the Permit Holder to prepare a full report to ensure adequate documentation;
- Will notify / submit reports to the Canadian Nuclear Safety Commission (CNSC) as required.
External Exposure (Not involving contamination)

The most difficult and crucial step is to recognize that an abnormal situation has occurred, for example that the shutter of an irradiator failed to close, or a sealed source is on the floor instead of in its container.

It is therefore important for radiation workers to become thoroughly familiar with the normal appearance and operation of the sources and/or radiation-emitting devices with which they are working, especially if the devices or sources are capable of delivering a high dose-rate.

Once an accidental external exposure has been recognized, proceed as follows:

- Immediately perform all necessary actions to prevent further exposure, e.g. switch off the irradiator, shield the radioactive sources, etc. In some circumstances, the exposed person cannot perform these actions on their own and must first call for assistance;
- Report the incident to the Permit Holder who, in turn, will inform the RSO;
- Make a preliminary estimate of the radiation dose(s) received by the exposed person(s), in co-operation with the RSO. It is better, at this stage, to overestimate rather than underestimate. A more definitive dose estimate is usually made later, when the dosimeter reading for the exposed person is determined;
- Obtain medical review/assessment/follow-up as warranted

Accidents involving Radioactive Contamination

Minor Accidents

In situations where the total activity is less than 100 exemption quantities of a radioisotope and there is no apparent contamination of personnel, the following procedures should be adopted:

- evacuate the immediate area of the incident (as warranted);
- secure entry to the area (as warranted);
- identify and isolate all workers and others who may be affected;
- Estimate the activity involved and the nature of the contamination;
- Confine the spill and prepare to decontaminate;
- Wear disposable gloves and lab coat and clean up the spill using absorbent paper and place the contaminated materials in a radioactive waste container;
- Wash with an appropriate detergent and disposable towels. Care should be taken not to contaminate oneself and to avoid the spreading of contamination;
- Perform a wipe test for contamination and then repeat decontamination steps until contamination levels are acceptable;
• Check hands, clothing and shoes for contamination;
• Report the spill and clean up to the supervisor and to the RSO who will review corrective actions taken;
• Chronologically record spill details and contamination monitoring details;
• Adjust inventory and waste records appropriately.

**Major Accidents**

Where the total activity is more than 100 exemption quantities and/or there is a non-negligible risk of radiation exposure, the following applies:

• Notify at once all other persons in the room and/or area;
• Evacuate the area, and persons not involved in the spill should leave immediately;
• Close off and secure the spill area to prevent entry and post warning signs;
• Monitor with a suitable detector the persons suspected to be contaminated and, if appropriate, proceed with the personnel decontamination measures;
• Estimate the activity involved and the nature of the contamination;
• Monitor the area with a suitable detector and estimate the total exposure expected for the personnel involved in the decontamination measures; this is not a simple procedure and it must be performed by trained personnel only;
• If the decontamination procedures are not expected to lead to a significant exposure for the personnel (i.e. less than 1mSv), and if no airborne contamination is expected follow the steps identified in the minor accidents section of the procedure. Otherwise, proceed as described in the “Accident involving radioactive dusts, fumes or gases” section of this procedure;
• Notify the RSO of the incident at the end of clean up procedures, so that the RSO will send a complete report to the CNSC as required.

**Accidents involving radiological dust, fumes or gases**

• Notify all other persons and vacate the room immediately. Call the Dalhousie emergency number (902) 494-4109 Halifax or (902) 893-4109 Truro;
• Evacuate the immediate area of the incident;
• Identify and isolate all workers and others who may be affected;
• Ascertain that all doors giving access to the room are closed and post warning signs to prevent non-authorized access. If possible, switch off air circulation devices;

• The RSO will provide assistance for decontamination, air monitoring, surveying persons suspected of being contaminated, laboratory inspection, and accident investigation and reporting.

**Personnel decontamination procedures**

The following procedures apply for personnel decontamination:

• Estimate the activity involved, the nature of the contamination and the affected area;

• Wash the affected area with mild soap and lukewarm water. Take care not to injure the skin, as it would provide a direct pathway for radioactive contamination into the body. If the spill is on clothing, the article must be discarded at once and left on the premises in a plastic bag or other closed container. Any spill on the skin must be flushed thoroughly. Showering is not advised before the local contamination is thoroughly cleansed;

• Notify the Radiation Safety Officer of the incident.

**Fires in the Proximity of Radiological Materials**

The emergency instructions applicable to the building concerned must be followed exactly. It is essential to report the location of radioactive sources to the firefighting teams and to estimate any additional risk, which these sources may present. Laboratory personnel should see that the door to the radiation area is closed and take reasonable measures to prevent the combustion of nuclear substances.

Regional Fire Services will survey the premises at the end of the emergency before authorizing access to the premises to ensure that there is no significant risk of radiation exposure.

**Transport Mishaps and Emergencies**

A dangerous occurrence during transportation includes situations that put the consignor, carrier, and/or consignee at risk. These situations include, but are not limited to, the following events as discussed in Section 36 of the *Package and Transport of Nuclear Substances Regulations*:

a) A conveyance carrying radioactive material is involved in an accident.

b) A package shows evidence of damage, tampering, leakage of its contents, or its integrity is degraded in a manner that may reasonably be expected to impair its ability to comply with these Regulations or its certificate.

c) Radioactive material is lost, stolen or no longer in the control of a person who is required to have control of it under the Act.
In the event of a dangerous occurrence the consignor, carrier, and/or consignee must immediately limit the extent of the dispersal and control access of the area to other individuals to control exposure. The consignor, carrier, and/or consignee must then have an expert come to assess the situation and report to the CNSC.

In any situation where the consignor, carrier, or consignee becomes aware of failure to comply with requirements they, and the other parties, must make a preliminary report to the CNSC, which includes the locations, circumstances of the failure to comply, and the action to correct. The consignor must be alerted to any dangerous occurrence which has arisen.

The consignor, carrier, and consignee must submit a full report to the CNSC within 21 days of any dangerous occurrence.

**Fatal Radiation Dose**

In any emergency situation, which could result in fatalities, the radiation hazard may be taken into account only if anyone could receive a large whole-body dose, i.e. 0.5 Sv or more. This level is greatly in excess of the normal limits for Nuclear Energy Workers.

The risk of receiving a life-threatening dose of radiation at Dalhousie University is extremely remote. In the event of a life-threatening accident (such as heart attack or serious fall), measures to save the life must be of primary consideration. Then the radiological aspects of the accident (such as possible spread of contamination) are secondary.

**Local Laboratory level procedures**

Lab level procedures are necessary to ensure the following requirements are met including:

- Maintaining a current emergency contact list.
- Ensuring emergency clean-up equipment is available and maintained in good condition.
- Ensuring employees are aware of the procedures to follow in the event of an emergency.
Title: Decommissioning - Renovations, Remodels, Moves, Terminations
Number: RSP – D.15
Date: 2000, reviewed 12/05; revised April 2017

Introduction:

Once a location has been licensed, it cannot be released from the CNSC’s regulatory control until it has been decommissioned and the location has been authorized for release by the CNSC. When all nuclear substance operations cease at any of the licensed locations, the CNSC must be advised, a written report must be submitted, and after CNSC authorization, these locations will be removed from the licence.

The Principal Investigator (PI) of each laboratory is responsible to the university for the safe use of nuclear substances and radiation devices, by all persons under their supervision, from the initial possession until it is safely and properly disposed of.

It is the responsibility of the PI to decommission the laboratory. The Radiation Safety Officer (RSO) is responsible to verify the completion of the decommissioning process.

The PI must ensure that the RSO receives advance notification in the following situations:

1. There is a planned move to new laboratory space.
2. There is expansion of current laboratory space (renovation).
3. There are changes to current laboratory space (renovation/remodel).
4. Work with nuclear substances ceases.
5. The PI leaves the university.

The laboratory will also be decommissioned under the direction of the Radiation Safety Committee (RSC) or the RSO, when there has been no nuclear substance work conducted within a laboratory holding a Nuclear Substance User Permit after a three (3) year period. The PI will be asked to surrender the permit and decommission the lab.

Procedure:

1. Notify the RSO prior to any of the above listed changes or moves, giving the following information:
   - PI, department, and phone number
   - Time and date of projected change or move
   - Location of laboratory
2. Collect all radioactive waste and dispose of it in an appropriate manner as outlined in Dalhousie University's **Management of Radioactive Waste** policy.

3. Consolidate all unwanted lead/plastic items (pigs, shields etc..) into one area for removal by the RSO.

4. Nuclear substances not designated as waste must be disposed of in one of the following ways:
   
   I. An inventory **transfer within the same department**
   
   II. An inventory **transfer within the university**
   
   III. An inventory **transfer to another institution**. In case of such a transfer only individuals with full TDG training will be permitted to ship. This task is normally carried out by the RSO. Documentation from the receiving institution must be forwarded to the RSO verifying that the receiving institution is licenced to receive the material and that the RSO has approved the transfer.

   See **Transfer of Nuclear Substances and Radiation Devices Policy** for further direction.

5. A wipe test survey must be done on all items that are in current use or had previously been **used with nuclear substances**. These results must be recorded in your Radiation Safety Records binder. Items found to be contaminated must be cleaned and resurveyed until removable contamination is below those limits as set out in Dalhousie University’s **ALARA Program**. Wipe test results must also be submitted to the RSO for review and verification.

6. A thorough lab survey must be conducted using both the direct survey method (if appropriate) and an indirect survey (wipe test). All rooms listed on the permit must be surveyed. All surveyed areas must include, but are not limited to:

   I. Laboratory benches
   II. Fume hoods
   III. Sinks
   IV. Floor areas
   V. Refrigerator/freezer (exterior and interior)
   VI. Door knobs
   VII. Telephone receivers
   VIII. On/off switches
   IX. Computers/electronics

   These results must be recorded in the lab’s Radiation Safety Records binder. Areas found to be contaminated must be cleaned and re-surveyed until removable contamination is below the set limits in Dalhousie University’s ALARA Program. Monitoring results must also be submitted to the RSO for review and verification.

7. Plans to clean, paint or renovate a vacated or occupied lab must be submitted to the RSO. Prior to any work beginning, the RSO must review and verify the most current wipe test results for the area and grant official clearance for the work to begin.
8. Once the monitoring results have been reviewed and verified by the RSO, the PI will be notified that they can proceed to the next stage of decommissioning.

9. **All radiation warning signs must be removed.** This would include warning signs on doors, the hazard identification sign updated, storage areas, sinks, fridges, freezers, equipment etc. All nuclear substance posters must be removed, as well as the permits and conditions. The RSO will visit the lab to give final certification that the lab has been decommissioned. The lab will then be removed from the list of approved locations for work with nuclear substances.

10. Any piece of heavy/bulky equipment transferred outside your laboratory must be certified “clear” by the RSO prior to removal by either Facilities Management or external professional movers.

11. The RSO must be consulted first, before the disposal of any nuclear substance or radiation devices. Some pieces of equipment contain a sealed source, such as liquid scintillation counters.

12. The PI must submit this policy to the RSO, signed by the PI and the Department Head. This is to ensure all parties are aware of the decommissioned space within their department.

13. PI needs to submit a “Record of Disposition of Radioactive Material” to the RSO, attached to this policy. This is to declare their intentions not to renew the permit and to inform the RSO of the whereabouts of any nuclear substances the PI may have possessed.

14. The RSO will verify the decommissioning process, after all the wipe tests have been reviewed and verified, and the proper documentation has been submitted.

15. The RSO will report to the CNSC any licensed decommissioned locations to have removed from the licence. This report will include the following:

   a. The decommission plan (if applicable).
   b. A complete account of the disposition of all nuclear substances and devices.
   c. A statement confirming the removal of all radiation warning signs.
   d. Final radiological survey results at the site where unsealed sources were stored.

Rooms within a location may be decommissioned and released by the RSO without forwarding the results to the CNSC, however all records must be maintained and made available for inspection by the CNSC. The RSO will maintain all decommissioning records.
I verify that the decommissioning procedure has been completed according to the procedures listed above. The laboratory is free of any Nuclear Substance and/or Radiation Device.

Principal Investigator
(Print Name)       Signature       Date

Department Head
(Print Name)       Signature       Date

RSO
(Print Name)       Signature       Date
Record of Disposition of Radioactive Material

WITH REFERENCE TO NUCLEAR SUBSTANCE USER PERMIT:

Number: ___________________  Expiring: ______________

Principe Investigator: ________________________________

Department: ________________________________

This is to certify that:

It is not my intention to renew the referenced Nuclear Substance User Permit and that:

_____________  1. No radioactive material is currently in my possession.

_____________  2. All radioactive material obtained on the above permit has been disposed of as per Dalhousie University guidelines

_____________  3. All radioactive material obtained and/or possessed by the above permit holder has been transferred to ____________________
whose permit number is ______________

_____________  4. Other (please specify):

______________________________________________

______________________________________________

______________________________________________

Signature: _______________________________________

Date: ____________________  ________________________

Received by: ________________________________

Radiation Safety Officer

Date: ____________________
Title: CNSC Reporting Requirements
Number: RSP –D.16.1
Date: March 1, 2008, April 2017

Introduction:

All radiation workers are obligated to report incidents involving nuclear substances or radiation devices to the Radiation Safety Officer (RSO). The RSO shall investigate incidents in order to mitigate the consequences of the incident, determine causes and contributing factors, identify appropriate corrective actions and report any required incidents according to regulatory requirements to the Canadian Nuclear Safety Commission (CNSC).

The Nuclear Safety and Control Act (NSCA) and the regulations put forth by the Canadian Nuclear Safety Commission (CNSC) state that every licensee who becomes aware of any of the following situations below shall make a report to the CNSC. Depending on the situation, different types of reports and timelines for reporting will be required. Most incidents require an immediate report by the RSO to inform the CNSC, by phone, of the incident to the CNSC Duty Officer, who is available 24/7. The Duty Officer can be reached at the following contact information: 613-995-0479 or toll free 1-844-879-0805. Following notification of the incident, the CNSC may require a formal investigation and a written report to be submitted within 21 days of the event occurrence.

<table>
<thead>
<tr>
<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>The commissioning of a licensed activity</td>
<td>Within 7 days of the commencement of the activity</td>
</tr>
<tr>
<td>for a period of &gt; 90 days</td>
<td></td>
</tr>
<tr>
<td>The decommissioning of a licensed activity</td>
<td>Within 7 days of decommissioning</td>
</tr>
<tr>
<td>Thyroid screening of personnel detects activity</td>
<td>An immediate preliminary report must be made</td>
</tr>
<tr>
<td>activity &gt; 10 kBq I-124, I-125 or I-131</td>
<td>followed by thyroid bioassay within 24 hours of detection</td>
</tr>
<tr>
<td>Or &gt;100kBq I-123</td>
<td>License condition (2601-7)</td>
</tr>
<tr>
<td>The licensee is required to submit an ACR</td>
<td>The report must be received by CNSC by April 30th</td>
</tr>
<tr>
<td>annually</td>
<td>of each year</td>
</tr>
<tr>
<td>Applicant Authority or RSO changes</td>
<td>15 days</td>
</tr>
<tr>
<td>Event Description</td>
<td>Reporting Requirements</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Exceeding of personal dose limits</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (RPR (16))</td>
</tr>
<tr>
<td>Changes to representatives of applicants and licensees</td>
<td>The change must be reported to the CNSC within 15 days</td>
</tr>
<tr>
<td>Loss or theft of nuclear substances, prescribed equipment of prescribed information</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (NSCA-27 (b) i)</td>
</tr>
<tr>
<td>Contravention of the Act in relation to an activity</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (NSCA-27 (b) ii)</td>
</tr>
<tr>
<td>Occurrence likely to result in exposure exceeding applicable dose limits</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (GNSCR-29 (1) b)</td>
</tr>
<tr>
<td>Unauthorized release of radioactivity to the environment</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (GNSCR-29 (1) c)</td>
</tr>
<tr>
<td>Situation or event requiring implementation of a contingency plan</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (GNSCR-29 (1) d)</td>
</tr>
<tr>
<td>Breach of security or act of sabotage at site of licenced activity– actual or attempted</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (GNSCR-29 (1) e)</td>
</tr>
<tr>
<td>Actual, threatened or planned work disruption, including any strike or possible strike</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (GNSCR-29 (1) f)</td>
</tr>
<tr>
<td>Serious illness or injury incurred or possibly incurred as a result of a licenced activity</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence (GNSCR-29 (1) g)</td>
</tr>
<tr>
<td>Incident Type</td>
<td>Reporting Requirements</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bankruptcy</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence. <strong>GNSCR-29 (1) j</strong></td>
</tr>
<tr>
<td>Deficiencies in records</td>
<td>A report must be submitted to the CNSC within 21 days of becoming aware of the deficiency.</td>
</tr>
<tr>
<td>Positive leak test – activity measured in excess of 200 Bq</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence.</td>
</tr>
<tr>
<td>Loss or damage to an exposure device or sealed source</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence.</td>
</tr>
<tr>
<td>Transportation – dangerous as defined in Section 19 of the “Packaging and Transport of Nuclear Substances Regulations”</td>
<td>An immediate preliminary report must be made to CNSC.</td>
</tr>
<tr>
<td>Transportation – damaged shipment</td>
<td>An immediate preliminary report must be submitted to CNSC and the Consignor followed by a full written report within 21 days.</td>
</tr>
<tr>
<td>Transportation – tampered with package</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence.</td>
</tr>
<tr>
<td>Transportation – undeliverable consignments</td>
<td>An immediate report must be submitted.</td>
</tr>
<tr>
<td>Use of more than 2 GBq for tracer studies</td>
<td>A request must be submitted to CNSC prior to intended use followed by a report to CNSC within 60 days of completion of the study.</td>
</tr>
<tr>
<td>Failure or weakening of any component which could have serious adverse effects on the environment, health and safety of persons or the maintenance of security</td>
<td>An immediate preliminary report must be made to CNSC duty officer, followed by an investigation of the occurrence, with a full written report submitted to CNSC within 21 days of occurrence. <strong>GNSCR-29 (1) g</strong></td>
</tr>
<tr>
<td>Discovery of inaccuracy in documents referred to in the appendix: License Documents</td>
<td>As soon as practicable License condition (2920-6)</td>
</tr>
</tbody>
</table>
Introduction:

The Canadian Nuclear Safety Commission requires that:

1. Every person who is required to keep a record by the Act, the regulations made under the Act or a licence shall retain the record for the period specified in the applicable regulations made under the Act or, if no period is specified in the regulations, for the period ending one year after the expiry of the licence that authorizes the activity in respect of which the records are kept.

2. No person shall dispose of a record referred to in the Act, the regulations made under the Act, or the license unless the person:

   a) is no longer required to keep the record by the Act, the regulations made under the Act, or the license; and

   b) has notified the Commission of the date of disposal and of the nature of the record at least 90 days before the date of disposal

It is the policy of Dalhousie University to generate and maintain radiation protection records, to use these records to protect individuals from unnecessary exposure, and to make these records available to the Canadian Nuclear Safety Commission (CNSC) upon request.

Other uses of these records may include:

   a) evaluation of the effectiveness of the radiation protection program;

   b) demonstration of compliance with regulations and requirements of both the CNSC and Dalhousie University Radiation Protection Program;

   c) other purposes as may be required

Dalhousie University requires that all applicable areas generate and maintain the occupational radiation protection program records and supporting information for their employees. Timely reporting of appropriate data is also required.

As a minimum, an acceptable radiation protection records program is one that:
a) has well documented policies and procedures for record and report generation and administration;

b) demonstrates timely record and report generation and retrieval capability;

c) includes a documented quality assurance plan for assuring accuracy and completeness;

d) maintains documents that are traceable, trackable, verifiable, and retrievable.

Records to be maintained by individual work areas:

1. List of authorized users and training
2. Occupational radiation exposure records (including fetal exposure)
3. Personnel bioassay screening records
4. Receipt of nuclear substance records
5. Inventory records of all devices and sources (accounting from the time of possession until disposed as waste)
6. Daily direct monitoring records
7. Weekly wipe test records
8. Use and Non-use periods
9. Incident reports of any type
10. All training certificates
11. Transport/transfer/shipping documents
12. All acquisition, transfer and/or transportation of nuclear substances and radiation devices documents
13. Type A package Certification
14. Any record of service or maintenance on radiation detection equipment

All Nuclear Substance Permit Holders must maintain records of receipt, inventory usage and disposal on the Environmental Health and Safety Assistant (EHSA). All records must reflect the “lifetime” of the isotope, from the time the isotope is acquired until the isotope has been disposed of. Timely maintenance of these records is required to ensure compliance with Dalhousie University Radiation Protection Program.
The above records shall be maintained in a format approved by the Radiation Safety Officer. Paper records are to be kept in the yellow binders provided by the Radiation Safety Officer. All other information is to be recorded in the online EHSA. These records must be up to date and available for inspection by the radiation safety officer (RSO) and/or officers of the CNSC at any time.

No documents are to be destroyed without requesting and receiving permission from the CNSC. The RSO will request in writing at least 90 days before the intended date of disposal, permission from the CNSC, to destroy the requested records.

**Records to be maintained by the radiation safety officer:**

1. Names of all occupationally exposed workers at Dalhousie University
2. Personal radiation exposure records of all occupationally exposed workers
3. Names and job categories of Nuclear Energy Worker’s (NEW) and NEW declaration forms
4. Training records for all radiation workers
5. Copies of all active Nuclear Substances and Radiation Devices Licences and Nuclear Substance User permits
6. Listing of all locations where nuclear substances are used or stored
7. Inventory of radiation detection equipment
8. Radiation detection equipment calibration certificates
9. Inventory of all sealed sources with their required frequency for leak testing
10. Leak test records
11. Inventory of unsealed sources
12. Minutes from Radiation Safety Committee meetings
13. Incident reports
14. “Declaration of Pregnancy” forms
15. Decommissioning results
16. Radioactive waste disposal
17. Acquisition and transfers of nuclear substances and radiation devices
18. Records of Security audits performed
19. Any record of service or maintenance on radiation detection equipment

The above records shall be kept up to date and available for inspection by the CNSC at any time. These files may be found on paper, electronic files or online on the EHSA.
The possession, use, and storage of nuclear substances is regulated by the Canadian Nuclear Safety Commission (CNSC), with the issuance of a licence. Dalhousie University holds a consolidated licence from the CNSC, which allows the use of many nuclear substances and radiation devices throughout the university. The use and storage of nuclear substances is limited to the locations authorized by the CNSC licence. Based on the licence conditions, each area/location in possession, use, or storage of nuclear substances must be classified according to the CNSC’s area classification, licence condition #2108-3. These requirements are also outlined in the CNSC document Design Guide for Nuclear Substance Laboratories and Nuclear Medicine Rooms (GD-52).

Based on the licence conditions and GD-52, the nuclear substance laboratories receive a classification based on the type and amount of radioisotope requested for handling. GD-52 also states to hold an intermediate level laboratory permit, a Design Assessment Form (DAF) must be completed and submitted to the CNSC for approval. A DAF may also be requested by the CNSC for a Basic level laboratory.

If the area, room, or enclosure is used only for the storage of sealed nuclear substances or radiation devices, the laboratory classifications do not apply. Based on the CNSC laboratory classifications and Dalhousie University’s internal policy, nuclear substance laboratories will be classified as one of the following types of laboratories.

**Laboratory Classifications:**

*Exempt Laboratory:* A laboratory is classified as 'exempt level' when less than 1 EQ (exemption quantity) of a nuclear substance is handled.

*Basic Laboratory:* A laboratory is classified as 'basic level' when more than 1 EQ (exemption quantity) of a nuclear substance is handled and where the largest quantity (in Bq) handled by an individual worker does not exceed 5 times its corresponding ALI (annual limit of intake) in Bq.

*Intermediate Laboratory:* A laboratory is classified as 'intermediate level' where the largest quantity (in Bq) handled by an individual worker does not exceed 50 times its corresponding ALI (annual limit of intake) in Bq.

*Sealed Source Laboratory:* A laboratory is classified as “sealed source” when the only nuclear substances used in the lab are sealed sources or sealed sources within a device.

*Storage Only Laboratory:* A laboratory is classified as “storage only” when the Principal
Investigator solely possess nuclear substances. No work with nuclear substances is permitted.

Responsibilities:

Radiation Safety Officer:

1. Determine the laboratory classification of all initial requests for Nuclear Substance User Permits.
2. Ensure that the laboratory classification is correct with permit amendments and renewals.
3. Provide the required signage as required for the laboratory classification assigned.

Principle Investigator:

1. Must ensure the correct signage is posted in the laboratory to indicate the correct laboratory classification (located on the nuclear substance user permit).
2. Must understand the requirements of the laboratory classification.
3. Must follow all internal policies, irrespective of laboratory classification.
4. Labs with storage only permits are NOT allowed to work with nuclear substances. They may keep isotopes in their possession for storage purposes only.
Introduction:

Proper housing controls for research animals using radioactive materials are necessary to maintain the radiation dose received by any person. Exposures from external or internal sources of ionizing radiation must be kept to the lowest possible value consistent with effective use of the following procedures and must never exceed the legally maximum permissible dose limits.

Control of radiation exposure is based on the assumption that any exposure involves some risk. However, occupational exposures within accepted limits represent a risk, very small compared to the other risks voluntarily encountered in other work environments.

The policy at Dalhousie University is to maintain occupational exposures as low as reasonably achievable (ALARA). ALARA is a part of the normal work process involving people working with ionizing radiation. Management at all levels and in all areas, as well as each individual worker, must take an active role in minimizing radiation exposure.

Radiation use Protocol:

All individuals using nuclear substances in live animals under the control of the Dalhousie University “Nuclear Substances and Radiation Devices Licence” are to be advised of the following policy.

General Requirements

Prior to the start of nuclear substance work, it is the responsibility of the user to confirm and adhere to the “Conditions for Use” printed on the Nuclear Substance User Permit. In addition, to these conditions, the user, after consultation with the Animal care supervisor, is responsible for care of the animals injected with nuclear substances. This responsibility includes proper care, feeding and cleaning of the animals and cages, as well as approved handling of all animal wastes, bedding and cages.

All users must be gowned, masked, hair nets and shoe/boot covers.

Animal handlers are to double glove at all times when working in rooms with radiation hazard sign posting.

Double shoe covers shall be worn in all cases when the animal housed is a rabbit or large animal.

Dosimeters are to be worn at all times if required. Refer to Ascertaining and Recording Doses policy for further information on dosimeters.

Gloves and shoe covers must be removed and disposed of before exiting the room.
Animal Housing:

Animals treated with radioactive materials shall be quarantined appropriately in a room specifically designated for treated animals. In addition:

- Cages housing animals treated with radioactive materials must be posted with a radiation warning sign
- The dose rate in occupied or public access areas adjacent to the animal housing must not exceed the regulatory limits and the permit holder should be able to demonstrate that it will not increase a person’s effective dose by 500 μSv or more per year in excess of background radiation
- This room shall contain a decontamination kit in the event of a radioactive spill.
- Appropriate signs must be posted on the door where nuclear substances are used. The posted information must include the name, department, and phone number of the responsible person (principal investigator), the nuclear substance used and its activity, the RSO’s name and phone number, and the 24 emergency contact number. In addition an appropriate warning sign must be posted on the cage in which the animal is housed.

Animals injected with short lived isotopes:

The General Nuclear Safety and Control Regulations prescribe that measures to reduce the level of contamination in a place may be taken by a licensee in an appropriate manner and it may be more reasonable from an ALARA perspective to secure the area and let the radioisotope decay to minimal levels. Therefore, before the decontamination process is started, it may be warranted to secure the contaminated area and allow this material to decay to background radiation levels depending on the isotope. The general rule of thumb is to allow the isotope to decay for 10 half-lives. Therefore with the use of F-18, and a 110 minute half-life, closure would be necessary for a minimum of 24 hours. Tc-99m with a half-life of 6 hours would require a minimum of a 48 hour closure and I-123 with a 13 hour half-life would require a minimum of a 6 day closure.

Disposal of animal waste:

All animal waste (excrement and bedding) is to be treated as radioactive waste and disposed of in double plastic bags in the radiation disposal boxes kept in the animal room to avoid tracking contaminated waste throughout the facility.

Records shall be maintained to record the method of release and indicate the quantities of animal waste or emesis, released to municipal garbage systems, municipal sewers, the atmosphere and other destinations.

Local procedures are required to indicate the process for the disposition of any carcasses containing nuclear substances.
Monitoring and release of animal housing:

It is necessary to confirm that the housing for animals treated with nuclear materials will not be used for any other purpose until the level of radioactive contamination meets criteria for release or re-use. Including the following:

- All areas of animal housing should be monitored, cleaned, decontaminated, and decommissioned (if necessary) before being reoccupied.
- Prior to cleaning, the rooms, cages or other suspected contaminated equipment shall be monitored and wipe tested for any residual radioactivity. These results shall be recorded on the appropriate form and forwarded to the RSO for interpretation and release.
- Access to the area is restricted until the area has been decontaminated.

Onsite transportation of animals:

Where it is necessary to transfer animals within buildings, care shall be taken to prevent others from accidental exposure including the use of service elevators and avoiding public areas and using appropriate containment.

Offsite transportation of animals:

Where it is necessary to transfer animals off-site, both Director of Animal Care and the RSO require prior notification. The animal must be transported in an appropriately marked cage via a university vehicle. Appropriate care must be taken to ensure that any urine produced in transit can be contained to avoid unnecessary contamination of the vehicle. The animal must be accompanied by a member of the research group. Larger animals such as dogs must have a radiation warning sticker attached to their collar.

A “Transfer of Radioactive Material” form must be completed prior to the transfer.

If animals are transferred to an off-site location not covered by the Dalhousie University license prior approval must be received by the Director of Animal Care as well as the RSO. Since the move involves a transfer of radioisotope we must ensure that the receiving institution is licensed to use both the radioisotope in question as well as in vivo use in animals.

After transfer of the animal back to the Animal Care facility appropriate contamination checks must be done at the off-site location.
Introduction:

Dalhousie University is issued a Nuclear Substances and Radiation Devices Licence by the Canadian Nuclear Safety Commission (CNSC) to possess, transfer, import, export, use and store nuclear substances or radiation devices.

The Nuclear Substances and Radiation Devices Licence is a single broad-scope licence issued by the CNSC to an institution having many users of nuclear substances, with many different uses. The application for and issuance of a consolidated licence to an institution rather than to each individual nuclear substance user emphasizes to the institution its responsibility for a Radiation Safety Program.

Upon issue of this licence the university assumes the responsibility to ensure that any use of nuclear substances on campus complies with the Nuclear Safety & Control Act and regulations made under the Act, IAEA regulations (Regulations for the Safe Transport of Radioactive Material, 2012 Edition, being Specific Safety Requirements Series No. SSR-6, as well as conditions that apply to the licence.

The CNSC requires the following three components to be in place:

1. Radiation Safety Committee (RSC)
2. Radiation Safety Officer (RSO)

The Radiation Safety Officer is responsible for the day to day operations of the Radiation Safety Program and in conjunction with the Radiation Safety Committee, has the authority to implement and enforce the Radiation Safety Program encompassing the possession, use, handling, storage and disposal of nuclear substances.

The institution is visited by compliance inspectors from the CNSC to ensure that the regulations and licence conditions are being met by nuclear substance users. The CNSC has the ultimate authority to withdraw nuclear substance user privileges if serious violations are observed. A serious violation by one user could affect all those who use nuclear substances under Dalhousie University’s licence.
Internal Review and Enforcement Procedure

Each research group holding a Nuclear Substance User Permit, will be required to conduct a nuclear substance laboratory self-inspection, twice per calendar year. Any non-compliances shall be remediated in a timely fashion. The self-inspection report will be reviewed by the RSO. An audit of the laboratories shall be conducted by the RSO at regular intervals, on a risk based approach.

Any violations or non-compliances identified during the self-inspections, laboratory inspections or program audits will be categorized as either major or minor offences.

A major offence would result from violations which cause immediate risk or danger to safety, health, release to the environment of reportable quantities, doses of substantial amount to staff, or place the CNSC Nuclear Substances and Radiation Devices Licence in jeopardy. Examples of a major offence include:

a) contamination above licence criteria
b) inadequate monitoring program
c) use or storage of food or drink in the laboratory
d) inadequate training of staff
e) non-participation in required bioassay programs
f) refusal to wear required PPE (personal protective equipment)
g) inadequate security measures to safeguard nuclear substances
h) shipping or transferring radioisotopes without the knowledge of the RSO

A minor offence would be an infraction which poses no immediate risk or threat to health, safety, the environment or the licence. Examples of a minor offence would include:

a) inadequate warning signage
b) inadequate posting (permit, Dalhousie lab posters, CNSC information posters)
c) inadequate inventory records
d) frivolous use of signage
e) failure to wear required PPE
f) expired permit
g) failure to complete self-audit

MAJOR OFFENCE ACTIONS

1. On the first occurrence written email notification will be sent to the permit holder, with a copy to the department head, outlining the nature of the offence. Immediate attention to and correction of the violation is required.

2. On a second occurrence within a twelve month period the permit holder will be notified in writing that the permit will be revoked until a meeting can be held with the RSC. The permit holder may attend the meeting to explain why his/her permit should be renewed.

3. On a third occurrence within a twelve month period the permit will be cancelled and all inventory disposed of by the RSO.
For the second or third occurrences notification of the above actions will be copied to the appropriate Department Head and the Dean.

MINOR OFFENCE ACTIONS

1. On the **first** occurrence, the permit holder will be notified via email by the RSO of the violation observed.

2. On a **second** occurrence within a twelve-month period the RSO will send another email notification of the observed violation to the permit holder, with copies to the department head and the RSC.

3. On a **third** occurrence, within a twelve-month period the RSO will arrange to have the permit transferred to the Head of the department in which the permit holder does the majority of his/her work. If the department head agrees to assume responsibility all work will be under his/her direct control. The department head’s signature **must** appear on all purchase requisitions. Written notification of the above action will be sent to the Dean of the faculty.

4. On a **fourth** occurrence within a twelve month period the permit will be revoked. A meeting may be requested by the permit holder with the RSC at which time the permit holder may argue as to why the permit should be renewed.

Minor offences must be corrected within seven (7) calendar days.
Dalhousie University holds a consolidated Nuclear Substance and Radiation Devices licence issued by the Canadian Nuclear Safety Commission (CNSC). The licence sets forth the terms and conditions that must be met to maintain the licence. Licence condition 2115-4, allows for the issuance of internal permits for researchers within individual laboratories, provided all license requirements are fulfilled. The internal permit system is used to coordinate and authorize all uses, isotopes, quantities and locations of nuclear substances and radiation devices throughout Dalhousie University. Use of ANY nuclear substance is strictly forbidden without the knowledge and issuance of an internal permit by the radiation safety officer.

Definitions:

**Environmental Health and Safety Assistant (EHSA):**

An electronic database used to store data for safety programs at Dalhousie University. This system allows for the creation of internal permits, maintains radioisotope inventory and usage, tracks waste disposal, maintains worker training courses and authorized workers. All requests for internal permits must be completed through this system, as well as permit amendments and renewals.

**Internal Permit or Nuclear Substance User Permit:**

A document issued by the Radiation Safety Officer (RSO) which allows individual researchers to possess, use and store nuclear substances, within the confines of the university licence. All conditions of the permit must be maintained, as per internal policy and CNSC regulations.

**Licence condition 2215-4:**

States that internal authorization may be granted to individual researchers provided the licensee ensures that:

- a) Internal authorizations are issued in accordance with the licensee’s internal authorization policies and procedures approved by the Commission or a person authorized by the Commission;

- b) Internal authorization forms are posted in a readily visible location in or near each room, area or enclosure where nuclear substances and radiation devices are used or
stored.

c) The licensed activity is conducted in accordance with the terms and conditions of the internal authorization.

**To apply for a nuclear substance user permit:**

1. Contact the RSO or Environmental Health and Safety (EHS) Client Liaison and Support Person for further direction and training. See the Dalhousie Environmental Health and Safety website for contact information.

2. Training will be scheduled and access given to the Environmental Health and Safety Assistant (EHSA).

3. Once training is completed, the researcher will complete and submit the electronic application form to apply for an internal nuclear substance user permit.

4. The RSO will review the application form.

5. Upon acceptance of the application, a meeting will be arranged with the RSO for consultation, approval of the laboratory location, setup, and review of the policies and procedures for the radiation safety program.

6. If an application is denied, a meeting will be arranged to discuss the rationale for the decision.

**Internal permits will contain the following information:**

1. Name of the authorized person internal to the licensee (Principle Investigator),

2. Permit number and current CNSC licence number

3. Issue and expiry dates

4. Laboratory classification

5. Approved use/ authorized activities

6. Approved nuclear substances and possession limits

7. Approved devices containing nuclear substances and maximum source limits

8. Approved locations: rooms, areas and enclosures where the nuclear substance is used or stored

9. Approved workers to use nuclear substances and training dates

10. Disposal methods

121
11. Conditions for the use of any nuclear substance user permit

12. Special conditions for the use of the individual permit holder

**Principle Investigator Responsibilities:**

1. Receive appropriate training to access the EHSA and complete permit application
2. Meet with the RSO to discuss all policies and procedures of the radiation safety program, proper laboratory set-up and requirements
3. Display permit within the spaces approved by the permit
4. Ensure workers are appropriately trained
5. Maintain the permit
6. Meet and maintain all conditions of the permit
7. Use the EHSA system to record and maintain all necessary data, such as inventory, inventory usage, waste disposal, training dates
8. Use the EHSA system to request permit amendments and renewals
9. Provide the necessary equipment, devices and PPE’s as required to work with nuclear substances under the confines of the university licence

**RSO Responsibilities:**

1. Facilitate training for the use of the EHSA
2. Review permit applications and ensure requests fall within the confines of the university licence
3. Create permits for individual researchers
4. Meet with the PI to discuss all policies and procedures of the radiation safety program, proper laboratory set-up and the necessary requirements
5. Review the permits as necessary for amendments, renewals, non-use and accuracy
6. Ensure permits are displayed in all appropriate areas
7. Maintain the university licence to reflect the requested activities of the researchers.
Conditions under which permits will be issued:

1. Internal permits must be displayed in or near each room, area or enclosure where nuclear substances are used or stored

2. Permits are issued to Dalhousie University faculty and staff members at the discretion of the RSO

3. All conditions of the permit must be maintained

4. Permits are approved for approximately two (2) years. Permits may be revoked by the RSO or the CNSC at any time due to continued non-compliance or in the case of a serious violation which could cause immediate harm to a person, the environment or the licence.

5. A PI that has not performed work with nuclear substances within a three (3) year period must surrender their permit and decommission the lab. This request to surrender the permit can come from the RSO or the Radiation Safety Committee (RSC)

6. If permit holder has been asked to surrender their permit, and is in possession of any radioisotopes they would like to maintain, they will be provided the option to change their permit status to “Storage Only”. This allows for the storage of the isotopes only. No work with the nuclear substances is permitted. To begin working with the isotopes at a later date, the RSO must first grant permission and will then reinstate the permit as required to work. Those holding a “Storage Only” permit will have limited access to the EHSA; a read only access will be given.

7. Written authorization must be obtained from the CNSC prior to issuing any internal authorization permit for any work requiring the use of more than 10,000 exemption quantities of a nuclear substance at a single time. In the event of this type of request, the RSO will ask for permission from the CNSC. Once permission is granted by the CNSC, the RSO will generate the permit for the requested use.
Section 8 – Radiation Safety Procedures

NUCLEAR SUBSTANCES

The purchase, use and disposal of nuclear substances is strictly controlled by the Canadian Nuclear Safety Commission (CNSC). Permission to use nuclear substances must be licensed accordingly. Requirements are set out in the following sections, as well as regulations, procedures and guides to good practice.

Licence Requirements & Permits

Dalhousie University is issued a Consolidated Nuclear Substances and Radiation Device Licence by the CNSC. The licence authorizes the university to issue Nuclear Substance User Permits for the use of nuclear substances and radiation devices on campus. In this manual the word “licence” refers to authority granted by the CNSC; the word “permit” refers to a document issued by the Radiation Safety Officer.

Nuclear Substance User Permits

Individuals who plan to use nuclear substances shall complete a permit application on the Environmental Health and Safety Assistant (EHSA); this will require training to complete. Contact the RSO or review policy “Internal Permit Authorization” for further direction.

The Radiation Safety Officer may request other relevant details prior to approval. Typically permits are processed by the Radiation Safety Officer, however, there may be instances where an application will be reviewed by the Radiation Safety Committee prior to approval.

Permit holders shall comply with all conditions forming part of the permit.

Permit Amendments

There will be occasions when it is necessary to add or delete items from a permit, or vary the purpose for which the permit was approved. Permit holders desiring amendments must submit an amendment through the EHSA with the requested change.

Permit Renewals

Routinely Nuclear Substance User Permits are issued for two years. Renewal of an existing permit must be requested through the EHSA. Notification will be sent to the PI as a reminder of the expiration date of the permit.

Nuclear Substance Purchase

Once an individual has received a Nuclear Substance User Permit the Purchasing Policy shall be followed. All purchases of nuclear substances and radiation devices must be authorized by the RSO.
Purchases of nuclear substances cannot be processed using a credit card, as each purchase must be verified by the RSO prior to processing.

**Import / Export**

The consolidated **Nuclear Substances and Radiation Devices Licence** allows for the import and export of particular nuclear substance. The permit holder must apply for an import or export licence from the CNSC. For further information contact the RSO.

**Inventory**

It is the responsibility of every permit holder to maintain up-to-date and accurate records of all nuclear substances purchased as well as the use and disposition of that material. Records **shall** be maintained in the electronic database, EHSA. Under no circumstances shall the inventory exceed the possession limits as defined on the Nuclear Substance User Permit. Any loss or theft of a nuclear substance **shall be reported immediately** to the Radiation Safety Office.

**Nuclear Substance Laboratory Facilities**

Laboratory classification will depend on several factors including - the amount of nuclear substance used, the type of operation performed, and the radiotoxicity of the nuclear substance. Facilities must be approved by the RSO prior to any work beginning with nuclear substances. Renovations or new facilities **shall** meet CNSC’s requirements in Regulatory Guide **GD-52, “Design Guide for Nuclear Substance Laboratories and Nuclear Medicine Rooms”**. New or renovated Intermediate Laboratories must have prior approval by the CNSC. The approval process will be co-coordinated through the Radiation Safety Officer.

**Decommissioning of Nuclear Substance Laboratories**

If a PI vacates a lab, or work with nuclear substances ceases it is necessary to decommission the laboratory. See **Decommissioning Policy** for details.

**UNSEALED NUCLEAR SUBSTANCES**

The use of unsealed sources of nuclear substances is customary in many research projects for a variety of reasons. As well as a potential hazard from **external radiation exposure**, these materials present a potential **internal radiation exposure hazard**. The most common routes of entry into the body are **ingestion, inhalation, absorption through open wounds**, and **absorption through intact skin**.

**Hazards**

There are three main hazards in handling unsealed sources of nuclear substances. These are:

1. skin contamination and/or deposition into the body
2. spread of contamination
3. external beta (β) and gamma (γ) radiation exposure
The important characteristics of the most commonly used nuclear substances are shown in “Nuclear Substance Data Sheets”. For nuclear substances not listed please consult with the RSO or the EHS website for a link to the CNSC Radionuclide Information Booklet.

Precautions for Handling Unsealed Nuclear Substances

The following precautions are given for the handling of unsealed nuclear substances. These guidelines are provided for the protection of personnel working with nuclear substances as well as to avoid contamination of other workers, adjacent work areas and sensitive equipment.

The protection of individuals from external radiation hazards is a relatively simple matter. It is achieved by the control of time worked and working distances from the source, in conjunction with the use of appropriate shielding materials - Time, Distance, and Shielding. Protection from internal radiation hazards is best achieved by the prevention of bodily contamination. Ingestion, inhalation and absorption are the principle routes of entry into the body. Preventative measures include, adequate ventilation, containment, PPE, and immaculate hygiene. With the exception of accidents, poor laboratory technique and poor radiation hygiene are the chief causes of internal contamination among workers.

The following rules shall be observed when working with unsealed nuclear substances. More thorough training is required by all workers handling nuclear substances. This shall be achieved by attending a Radiation Safety Training workshop conducted by the Radiation Safety Officer and by reading the Radiation Safety Manual and the Radiation Safety Training Manual. Retraining is required every three years.

- Confine experiments to trays lined with disposable absorbent liners; use bench liners on workbenches wherever practical.
- Confine operations to a fume hood wherever practical.
- **Do not pipette radioactive solutions by mouth.**
- **Do not eat, drink, smoke, store food or apply cosmetics in a nuclear substance laboratory.**
- Avoid direct contact with nuclear substances, wear all necessary/required PPE.
- Do not remove PPE from the laboratory unless it is known to be free from contamination.
- Open cuts and abrasions on hand should be bandaged and double gloves worn to prevent absorption.
- Always monitor hands, clothing and shoes for contamination before leaving the laboratory.
- **Always wash hands** prior to leaving the laboratory.
• Conduct required weekly contamination surveys of work areas and general laboratory areas and keep records in the binder provided by the Radiation Safety Office. Non-use periods must be noted.

• Always use a fume hood if the nuclear substance in use is volatile, or when the procedures generate gases, aerosols, vapors or dust.

• Use a glove box for work with dry radioactive powders.

• Segregate contaminated glassware and equipment from clean.

• Identify all equipment used with nuclear substances.

• Have a radiation monitor (if required) available and turned on when working with nuclear substances, remembering that these instruments are insensitive to radiation produced by weak beta emitters for which special monitoring (LS counting) is required.

No person shall work with nuclear substances until they are registered with the Radiation Safety Officer and have received some basic training in radiation safety as approved by the Radiation Safety Officer.

SEALED SOURCES

A sealed source is radioactive material contained in a sealed capsule, sealed between layers of non-radioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means. The confining barrier prevents dispersion of the radioactive material under normal and most accidental conditions related to the use of the source. In a general laboratory a sealed source can be a calibration source, check source, internal standards, plated sources or irradiators. They are generally gamma emitters. Some plated sources, however, are beta emitters such as $^{63}$Ni used in gas chromatography.

The inventory and leak testing of sealed sources is regulated under the conditions of Dalhousie University’s consolidated licence issued by the CNSC. The process begins and the paper trail begins when the source is requested for purchase. Once the source has been received a source identification number will be assigned by the Radiation Safety Officer and added to the university’s sealed source inventory.

General Hazard

Sealed sources are primarily an external hazard. They present an exposure potential to individuals close to the source. Sealed sources are used to check portable survey meters, liquid scintillation counters, as well as in research applications, such as gas chromatography studies and Mossbauer studies.
Sealed sources should be handled as if they are contaminated (i.e. gloves and remote handling tools). The basic principles of radiation protection applied to the use of sealed sources are:

- **TIME**
- **DISTANCE**
- **SHIELDING**

**Sealed Source Accountability**

Each lab in possession of sealed sources must maintain an inventory of these sources. The inventory process should include:

- source location
- labeling and Radiation Safety # for identification
- isotope
- activity
- assay date
- manufacturer
- serial #
- model

**Leak Testing of Sealed Sources**

Leak testing of sealed sources is conducted in accordance with the CNSC regulations.

Refer to Policy: Sealed Source Leak Testing (for details).

**NUCLEAR SUBSTANCE DISPOSAL**

General responsibility for policies regarding the disposal of nuclear substances rests with the Radiation Safety Officer. The control, safe packaging, and identification of radioactive waste, transportation, and any costs involved are the responsibility of the individual user. It is important that radioactive waste produced at the university be disposed of in compliance with Dalhousie University’s “Management of Radioactive Waste” policy.

In some circumstances waste materials may be returnable to the supplier. More commonly, disposal will take place by direct discharge to the environment, storage for decay, or shipment to an approved waste management site. The choice of disposal method requires consideration of the type of nuclear substance, its level of activity and its physical and chemical form. Consideration must also be given to any hazards arising from regulations applicable to non-radioactive components of waste.

*For any type of radioactive waste disposal, consult the RSO.*

One of the conditions of the Nuclear Substance User Permit is that inventory records be maintained. Such records **shall** include the location and methods of disposal for all radioactive wastes. All disposal records will be kept in the EHSA.
EXPOSURE TO PERSONNEL

Personal Dosimeters

Personal monitoring devices are worn to record cumulative doses received as a result of occupational exposures to external radiation. Most applications are to obtain an approximation of whole body dose, but dosimeter units are available to measure localized areas (e.g. fingers). Information obtained when the dosimeters are read is useful for evaluating the effectiveness of protective measures and the necessity of appropriate action (especially if overexposure is indicated).

Reports of personnel exposures are reviewed by the Radiation Safety Officer and then forwarded to the department or lab. All workers should review their dosimetry records on a quarterly basis.

The RSO will investigate any unusual exposure after consultation with the worker in question and advise corrective action where indicated for the health and safety of personnel. The RSO is required to investigate and report to the CNSC on the circumstances of any exposure report exceeding maximum permissible dose limits as stipulated in the Nuclear Safety & Control Regulations.

Radiation Exposure Limits

All researchers who work with nuclear substances or radiation devices shall be appropriately designated as authorized radiation workers and provided radiation safety training in accordance with the identified hazards of their specific job.

At Dalhousie University, there are two classifications of radiation workers. Nuclear Energy Workers (NEW’s) and Non-Nuclear Energy Workers (Non-Nuclear Energy Workers). Individuals working with radiation that have the potential for receiving annual doses exceeding the general public limits, will be designated as NEW’s. Those individuals working with radiation who do not have the potential for receiving annual doses exceeding the general public limits, will be designated as Non-NEW’s. The radiation Safety officer will be responsible to determine the appropriate designation.

It should be noted that the setting of a dose limit is equivalent to specifying a maximum acceptable level of risk. Nevertheless, it is not acceptable to be exposed to the full extent of the limit if a lower dose can be reasonably achieved (ALARA).
Bio Screening Programs

Safe working procedures will minimize the likelihood of ingesting, inhaling, or absorbing nuclear substances into the body. For some types of work, however, routine Bio screening is a regulatory requirement. Routine bio screening in these cases will give warning if working conditions or procedures require improvement or are potentially unsafe. Bio screening programs seek to detect internal contamination by measurement of radioactivity in biological samples such as blood or urine or by direct in vivo measurements (external thyroid counting). Thyroid screening requirements at Dalhousie University are contained in the policy, “Thyroid Monitoring, Screening and Bioassay”.

<table>
<thead>
<tr>
<th>Item</th>
<th>Person</th>
<th>Period</th>
<th>Effective Dose Limits (mSv)</th>
<th>Dalhousie Action Level (mSv/quarter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nuclear energy worker (NEW) including a pregnant nuclear energy worker</td>
<td>(a) One-year dosimetry period</td>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) Five-year dosimetry period</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Pregnant Nuclear Energy Worker</td>
<td>Balance of the pregnancy</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>A person who is not a nuclear energy worker</td>
<td>One calendar year</td>
<td>1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**RADIATION WARNING SIGNS AND NOTICES**

**Requirements:**

1. Every licensee who is required under section 21 of the Radiation Protection Regulations to post a sign shall:
   a. post and keep posted, in a visible location at the place where the radioactive nuclear substance is used or stored, a durable and legible sign that indicates the name or job title and the telephone number of a person who can initiate any required emergency procedure and who can be contacted 24 hours a day; and
   b. post and keep posted, in a visible location at every personnel access opening to any equipment fitted with a radiation device, a durable and legible sign that bears
      i. the radiation warning symbol set out in Schedule 3 to the Radiation Protection Regulations and the words “RAYONNEMENT — DANGER — RADIATION”, and
      ii. the requirement to follow the personnel entry procedures required by the licence.
2. Whenever the radiation warning symbol set out in Schedule 3 is used,
   a. it shall be
      i. fully visible,
      ii. of a size appropriate for the size of the container or device to which it is
          affixed or attached, or the area, room or enclosure in respect of which it is
          posted,
      iii. in the proportions depicted in Schedule 3, and
      iv. oriented with one blade pointed downward and centered on the vertical
          axis; and
   b. no wording shall be superimposed on it.

Radiation Warning Symbol

NOTE:
The three blades and the central disk of the symbol shall be:
   a. magenta or black; and
   b. located on a yellow background.

3. No person shall post or keep posted a sign that indicates the presence of radiation, a
   nuclear substance or prescribed equipment at a place where the radiation, nuclear
   substance or prescribed equipment indicated on the sign is not present. Inappropriate
   use of signage is a non-compliance referred to as frivolous use of signage.

4. Proper warning signs must be posted where there is a radioactive nuclear substance in a
   quantity greater than 100 times its exemption quantity and/or where there is reasonable
   probability that a person might be exposed to an effective dose rate of greater than 25
   µSv/h. The effective dose rate in the laboratories will be measured during the semi-
   annual self-inspection, as well storage and waste areas, which must be kept under 2.5
   µSv/hr. Measurements exceeding 2.5 µSv/hr must be reported to the RSO immediately.

5. CNSC requires to post the name, job title and telephone number of an individual with the
   appropriate authority who can be contacted 24 hours a day in case of an emergency.

6. Dalhousie University requires that ALL laboratories in which nuclear substances or
   radiation devices are present shall have posted at each entrance to the lab, a Dalhousie
   University Hazard Identification sign posted which will include the identification of any
   nuclear substances or radiation devices.

7. A copy of the Dalhousie University poster “Basic Level Laboratory - Nuclear
   Substance Safety” or “Intermediate Level Laboratory - Nuclear Substance Safety”
   must be posted in each laboratory where nuclear substances are used or stored. The
poster shall include the names as well as twenty four hour contact information to be used in case of an emergency.

8. The Nuclear Substance User Permit with all attachments must be posted in any room where nuclear substances are used or stored.

9. A copy of the CNSC information posters, Spill Procedures, Proper Care and Use of Personal Dosimeters, and Guidelines for Handling Packages Containing Nuclear Substances should be posted within the laboratory, where applicable.

10. Cupboards, cabinets, refrigerators, and other containers used to store nuclear substances must be identified with a radiation warning label and 24 hour emergency contact information. These areas shall be secured against unauthorized access with a locking system approved by the Radiation Safety Officer.

11. Primary storage containers must be identified with a radiation warning symbol and information respecting the nature, quantity and date of assay of the nuclear substance contained within.

NUCLEAR SUBSTANCES IN TEACHING PROGRAMS

This section applies to those instances where students at Dalhousie University (usually undergraduate) may have occasion to handle nuclear substances as part of classroom or laboratory exercises connected with the classes in which they are enrolled. Such activities must be undertaken with the utmost concern for the safety of the students involved and the following conditions must be observed:

a) All nuclear substances used for teaching purposes must be covered by a current Nuclear Substance User Permit. It is not necessary that a unique permit be obtained specifically for teaching purposes, nor that the permit holder be the instructor for the exercises in question, although this may be convenient. The permit holder, must however, be fully conversant with the work done and assume full responsibility for the use of nuclear substances and the safety precaution to be taken.

b) The instructor must be qualified in the safety aspects of procedures to be performed so as to provide adequate supervision and advice to students. Further, instructors must know proper procedures to follow in event of spills, accidents and emergencies and to be prepared to give competent leadership to students as required.

c) Special care must be taken to ensure that the possibility of exposure to the participants and observers to external exposure or contamination is kept as low as reasonably achievable (ALARA).

d) Before undertaking any project requiring the handling of nuclear substances, students must be given clear and complete instruction in the radiation safety aspects of the procedures.

e) Adequate protective clothing for the procedures at hand must be available and worn by all students participating.
f) For the mutual protection of both students and the University, class instructors are required to complete “Teaching Laboratory Enrollment Form” available from the Radiation Safety Office or on the EH&S website at http://www.dal.ca/safety. Students are required to read the attached form “Safe Handling of Nuclear Substances”. Copies of this form should be filed with the Radiation Safety Office as soon as possible after classroom memberships are established.

g) The RSO must be notified immediately of any incident involving loss of a nuclear substance, injury or personal contamination, however minor.
Section 9 – Emergencies

RADIOACTIVE CONTAMINATION

Any work with unsealed nuclear substances involves the possibility of radioactive contamination, with consequent risk to personnel of subsequent ingestion and of interference with accurate measurements. Good operating methods as described in previous sections together with careful cleaning will normally keep contamination to an acceptably low level. However, spills and accidents will happen, causing contamination. Radiation workers must be prepared to cleanup (decontaminate) all identified radioactive contamination.

Radioactive Spills

Spills are the most likely type of incident to occur in a laboratory operation involving the use of open source nuclear substances. Most of these spills will involve only minor quantities of radioactivity and can be dealt with at the time by laboratory personnel.

The Radiation Safety Officer must be consulted for advice in any of the following situations:

i. a spill involving a nuclear substance of very high radiotoxicity

ii. a spill involving contamination of inaccessible areas

iii. a spill involving more than 100 exemption quantities (EQ’s) of activity

iv. a spill involving the release of volatile material

v. a spill involving the contamination of personnel

vi. when reasonable efforts to decontaminate are not successful in reducing activity to less than twice background

vii. when there is any doubt concerning appropriate decontamination procedures

Spill Clean-Up Procedure

The spill clean-up procedure is detailed in CNSC “Spill Procedures” information poster, which is to be posted within the laboratory.

Decontamination of Personnel

If contamination of personnel is suspected, have a colleague identify contaminated areas of the body with a suitable contamination meter or other suitable detection method. By having a colleague perform the survey, contamination of the survey instrument is avoided.
**If skin is intact:**

- Flush the area with copious amounts of *tepid* water
- Wet area and apply a mild soap
- Work up a good lather, keep lather wet
- Work lather into the contaminated area by rubbing *gently* to avoid damaging the intact skin. This process should be continued for three minutes, applying water frequently
- Rinse thoroughly with *tepid* water
- Repeat above procedures twice, if necessary
- If residual activity remains after three attempts to decontaminate, obtain assistance from the RSO

**If minor cuts, abrasions or open wounds** which do not warrant treatment at the hospital are observed:

- Dry clean the affected area with suction and swabs
- Using wet swabs, work away from the area of open wounds taking care not to spread activity over the body or into the wound
- Obtain advice from the RSO

**If ingestion of the nuclear substance has occurred, dial 4109 immediately. Security will notify the RSO.**

**ACCIDENTS**

Even in the best run laboratories accidents occasionally occur. Those involved must be fully conversant with emergency procedures to be followed in the event of an accident involving a nuclear substance.

In any incident of an emergency nature (including all which involve significant personal injury) **security must be contacted immediately at 4109**, they will in turn contact the RSO who will assist in the further management of the emergency. **No person shall resume work at the site of an emergency until authorized to do so by the RSO.**

Any radiation incident which qualifies as an emergency must be followed by a formal incident report submitted to the Radiation Safety Officer. The RSO may request reports of non-emergency incidents as well, and it is important to keep notes of all incidents, however minor, for future reference.

No set of guidelines can anticipate all potential emergency situations. The need for good judgement and prompt correct action is crucial. It follows, that specific procedures for meeting emergencies should be worked out in advance for the particular circumstances in each laboratory project. These must be known and understood by all workers involved.
In the event of **personal injury**, the treatment of the injury **must take precedence**, even with contaminated personnel. It may, however, be possible to **“contain”** any contamination by confining all such persons to the same area and immediately notifying Security at 4109, who will in turn notify the RSO. Universal precautions should be incorporated.

**Minor injuries**, should be treated at, or near, the scene of the incident. Wash any wound under tap water with copious amounts of tepid water and encourage bleeding. If the wound is on the face take care not to contaminate the eyes, mouth or nostrils. Wash the wound with soap and tepid water and apply a clean first aid dressing. The injured area should be monitored to establish the level of residual activity, if any.

**The treatment of serious injuries must take precedence over all other considerations.** The injured person, if moveable, should be transported under escort to the Emergency Department. The Emergency Department should be warned of the patient’s arrival and given the following information:

1. Name(s) of patient(s)
2. Nuclear substance involved
3. Total activity involved
4. Physical form of nuclear substance (powder, liquid)
5. Chemical form of nuclear substance
6. Extent of contamination (skin, inhalation, ingestion)
7. Nature of injuries

**FIRE**

In the event of fire, personnel **must** follow Dalhousie University’s fire procedures for the area. Laboratory personnel should see that the door to the radiation area is closed and take all reasonable steps to prevent the combustion of nuclear substances. Security should be contacted immediately at 4109 who will in turn notify the RSO. Before reentry after a fire you must check for radioactivity. Fire may have melted the lead which was protecting workers from radiation. This could lead to radiation exposure if not checked.

See policy, “Radiation Emergency Procedures”.
DALHOUSIE UNIVERSITY
TEACHING LABORATORY ENROLLMENT FORM

1. Permit Holder: ________________________ Permit #: ________________________

2. Instructor: ___________________________ Department: _______________________

3. Phone Number: _______________

4. Class Title: _____________________________________________________________

5. Dates of sessions in which Nuclear Substances will be used:
   _______________________________________________________________________

6. Rooms where above sessions will be held: __________________________________

7. Nature of work that students will undertake:
   _______________________________________________________________________
   _______________________________________________________________________

8. List Nuclear Substances and activity of each that a student will handle:
   _______________________________________________________________________
   _______________________________________________________________________

9. List of students (complete page two)

Date: ________________________ Signature: ________________________

Department Chair/Head ________________________

Form#: RS-004

The instructor and permit holder shall be responsible for the safe use of nuclear substances by all involved.

_________________________________   ______________________________
NAME                               DATE OF BIRTH
SAFE HANDLING OF NUCLEAR SUBSTANCES

There are three main hazards involved when working with open sources of nuclear substances. These are:

- **Skin contamination and/or deposition of nuclear substances in the body**
- Spread of contamination
- **External radiation**

In teaching laboratories students handle very small quantities of nuclear substances, so generally, the hazard from external radiation is minimal. The main hazards are spread of contamination and internal deposition of the nuclear substance.

Spread of contamination is controlled by:

- **Containment**
  - use of spill trays (double containment)
  - use of absorbent pads
- **Cleanliness**
  - good housekeeping
  - regular weekly wipe testing
  - good personal hygiene

Nuclear substances can be internally deposited by the following routes of entry into the body:

- Direct **inhalation** of airborne contamination (volatility, droplets, particulates)
- **Ingestion**, that is entry through the mouth
- **Absorption** through intact skin or a contaminated wound

Once nuclear substances are inside the body they may be selectively concentrated in one or more organs referred to as **critical or target organs**. These target areas will continue to be irradiated until the nuclear substance has decayed or the body has biologically eliminated the substance.

To avoid the possibility of internal deposition of the nuclear substance the following laboratory rules **shall be strictly enforced**.

- Do not bring unnecessary personal items into the laboratory
- Wear proper protective clothing (lab coats, disposable gloves)
- **Do not eat drink, smoke, apply cosmetics or store food where nuclear substances are used.**
- Do not pipette by mouth.
- Line work benches with disposable absorbent pads.
- Label anything likely to become contaminated before the experiment begins.
- Define an area on the lined workbench where contaminated items are to be laid down.
- Radioactive waste is to be disposed of only in the containers provided.
- If a nuclear substance is spilled, immediately cover the area with absorbent paper and call for assistance from the demonstrator. If you become contaminated, stay at your work area to avoid spread of the contamination and immediately call for assistance from the demonstrator.
Hands must be thoroughly washed with soap and lukewarm water at the completion of your operation.

_I have read, understand and agree to comply with the above instructions:_

NAME: (please print) __________________________________________

CLASS TITLE:_____________________  INSTRUCTOR:______________________

DATE: _______________  SIGNATURE:________________________________

Detach form and return to the Radiation Safety Office. This form must be on file in the Radiation Safety Office in order to participate in the class.
**Tc-99m**

This page has been printed from the Canadian Nuclear Safety Commission’s (CNSC) *Radioisotope Information Booklet*. For references to the information provided, consult the booklet available at [http://www.nuclearsafety.gc.ca/eng/resources/radiation/radioisotope-information.cfm](http://www.nuclearsafety.gc.ca/eng/resources/radiation/radioisotope-information.cfm).

### Part 1 – RADIOISOTOPE IDENTIFICATION

| Chemical symbol: Tc | Common name: Technetium | Atomic weight: 99 | Atomic number: 43 |

### Part 2 – RADIATION

**Physical half-life:** 6.01 hours  
**Radioactive progeny:** Tc-99 (half-life = 2.11E+05 years, 100%)

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Most abundant emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Most energetic emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Shielding information (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma &amp; X-ray</td>
<td>140.51 keV (89%)</td>
<td>142.63 keV (0.019%)</td>
<td>Lead: $1^{\text{st}}$ HVL = 0.4, $2^{\text{nd}}$ HVL = 0.3, $1^{\text{st}}$ TVL = 1.1, $2^{\text{nd}}$ TVL = 15</td>
</tr>
<tr>
<td></td>
<td>18.37 keV (4.0%)</td>
<td>140.51 keV (89%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18.25 keV (2.1%)</td>
<td>20.60 keV (1.2%)</td>
<td></td>
</tr>
<tr>
<td>Beta(-), Beta(+), electrons</td>
<td>119.47 keV (8.8%)</td>
<td>142.05 keV (0.034%)</td>
<td>Practical range in glass:</td>
</tr>
<tr>
<td></td>
<td>15.50 keV (2.1%)</td>
<td>140.44 keV (0.037%)</td>
<td>0.2 Practical range in</td>
</tr>
<tr>
<td></td>
<td>137.47 keV (1.1%)</td>
<td>139.97 keV (0.19%)</td>
<td>plastic: 0.3</td>
</tr>
</tbody>
</table>

### Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

**External dose**

Dose rate to skin from direct contamination: 0.25 mSv/h per kBq/cm²  
Gamma ray effective dose rate at 1 m: 1.853E-05 mSv/h per MBq

**Internal dose**

<table>
<thead>
<tr>
<th>Worker dose coefficient</th>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.2E-11 Sv/Bq</td>
<td>2.9E-11 Sv/Bq</td>
</tr>
</tbody>
</table>

### Part 4 – CLEARANCE AND EXEMPTION

<table>
<thead>
<tr>
<th>CNSC exemption</th>
<th>100 Bq/g or 10 MBq</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNSC unconditional</td>
<td>100 Bq/g</td>
</tr>
</tbody>
</table>

**CNSC classification:** Class C  
**Surface contamination free-release criterion:** 100 Bq/cm²  
(fixed + removable)

### Part 5 – DETECTION AND MEASUREMENT

**Method of detection (dose rate):**

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

**Method of detection (contamination):**

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination  
3. Non-portable: liquid scintillation counter, NaI well counter

**Dosimetry**

External: Gamma/beta  
Internal: Whole body counting, urinalysis

### Part 6 – SAFETY PRECAUTIONS

When working with unsealed sources wear appropriate protective clothing, such as laboratory coats (which should be monitored before leaving the laboratory), coveralls, gloves, and safety glasses/goggles. Use a suitable mask if the radioactive material is in the form of dust or powder, or if it is potentially volatile.  
Optimize time, distance and shielding. Monitor equipment and supplies for loose contamination before removing from laboratory. Use disposable absorbent liners on trays.  
See appendix B for emergency procedures.
Cr-51

This page has been printed from the Canadian Nuclear Safety Commission’s (CNSC) Radionuclide Information Booklet. For references to the information provided, consult the booklet available at http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm.

<table>
<thead>
<tr>
<th>Part 1 – RADIONUCLIDE IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical symbol: Cr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 2 – RADIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical half-life: 27.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Most abundant emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Most energetic emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Shielding information (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma &amp; X-ray</td>
<td>320.1 keV (9.9%)</td>
<td>320.1 keV (9.9%)</td>
<td>Lead: 1&lt;sup&gt;st&lt;/sup&gt;HVL = 2.8, 2&lt;sup&gt;nd&lt;/sup&gt;HVL = 1.8, 1&lt;sup&gt;st&lt;/sup&gt;TVL = 7, 2&lt;sup&gt;nd&lt;/sup&gt;TVL = 5.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Steel: 1&lt;sup&gt;st&lt;/sup&gt;HVL = 30, 2&lt;sup&gt;nd&lt;/sup&gt;HVL = 12, 1&lt;sup&gt;st&lt;/sup&gt;TVL = 57, 2&lt;sup&gt;nd&lt;/sup&gt;TVL = 34</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Concrete: 1&lt;sup&gt;st&lt;/sup&gt;HVL = 119, 2&lt;sup&gt;nd&lt;/sup&gt;HVL = 45, 1&lt;sup&gt;st&lt;/sup&gt;TVL = 216, 2&lt;sup&gt;nd&lt;/sup&gt;TVL = 120</td>
</tr>
<tr>
<td>Beta(-), Beta(+), electrons</td>
<td>314.6 keV (0.015%)</td>
<td>314.6 keV (0.015%)</td>
<td>Practical range in glass: &lt;0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Practical range in plastic: &lt;0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS</th>
</tr>
</thead>
</table>

**External dose**

Dose rate to skin from direct contamination: 0.015 mSv/h per kBq/cm² Gamma ray effective dose rate at 1 m: 4.554E-06 mSv/h per MBq

**Internal dose**

<table>
<thead>
<tr>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker dose coefficient</td>
<td>3.8E-11 Sv/Bq</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 4 – CLEARANCE AND EXEMPTION</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>CNSC exemption</th>
<th>CNSC classification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kBq/g or 10 MBq</td>
<td>Class C</td>
</tr>
<tr>
<td>100 Bq/g</td>
<td>Surface contamination free-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 5 – DETECTION AND MEASUREMENT</th>
</tr>
</thead>
</table>

**Method of detection (dose rate):**

1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

**Method of detection (contamination):**

1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination

**Dosimetry**

External: Gamma/beta

Internal: Whole body counting, urinalysis

<table>
<thead>
<tr>
<th>Part 6 – SAFETY PRECAUTIONS</th>
</tr>
</thead>
</table>

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.
## Part 1 – RADIONUCLIDE IDENTIFICATION

<table>
<thead>
<tr>
<th>Chemical symbol</th>
<th>Common name</th>
<th>Atomic weight</th>
<th>Atomic number</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Iodine</td>
<td>125</td>
<td>53</td>
</tr>
</tbody>
</table>

## Part 2 – RADIATION

### Physical half-life: 59.4 days

**Radiation type** | **Most abundant emissions (≥10 keV, >0.01%)** | **Most energetic emissions (≥10 keV, >0.01%)** | **Shielding information (mm)**
--- | --- | --- | ---
**Gamma & X-ray** | 27.47 keV (74.4%) | 35.49 keV | Lead: 1<sup>st</sup> HVL = 0.02, 2<sup>nd</sup> HVL = 0.02, 1<sup>st</sup> TVL = 0.06, 2<sup>nd</sup> TVL = 0.04
| 27.20 keV (39.9%) | (6.7%) 31.00 keV | Steel: 1<sup>st</sup> HVL = 0.09, 2<sup>nd</sup> HVL = 0.1, 1<sup>st</sup> TVL = 0.3, 2<sup>nd</sup> TVL = 0.5
| 31.00 keV (25.8%) | (25.8%) 27.47 keV | Practical range in glass: <0.1

**Beta(−), Beta(+) electron** | 22.70 keV (20.0%) | 34.49 keV | Practical range in plastic: <0.1
| 30.55 keV (10.7%) | (2.1%) 30.55 keV | 34.49 keV (2.1%) 30.55 keV (10.7%) 22.70 keV (20.0%)
| 34.49 keV (2.13%) | (10.7%) 22.70 | 34.49 keV (2.1%) 30.55 keV (10.7%) 22.70 keV (20.0%)

### Shielding material:
- Lead: 1<sup>st</sup> HVL = 0.02, 2<sup>nd</sup> HVL = 0.02, 1<sup>st</sup> TVL = 0.06, 2<sup>nd</sup> TVL = 0.04
- Steel: 1<sup>st</sup> HVL = 0.09, 2<sup>nd</sup> HVL = 0.1, 1<sup>st</sup> TVL = 0.3, 2<sup>nd</sup> TVL = 0.5
- Practical range in glass: <0.1
- Practical range in plastic: <0.1

### External dose
Dose rate to skin from direct contamination: 0.021 mSv/h per kBq/cm²
Gamma ray effective dose rate at 1 m: 1.449E-05 mSv/h per MBq

### Internal dose

<table>
<thead>
<tr>
<th>Worker dose coefficient</th>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5E-08</td>
<td>1.4E-08 Sv/Bq (vapor)</td>
</tr>
</tbody>
</table>

### Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

#### Ingestion

- Worker dose coefficient: 1.5E-08 Sv/Bq
- Inhalation: 1.4E-08 Sv/Bq (vapor)

### Part 4 – CLEARANCE AND EXEMPTION

<table>
<thead>
<tr>
<th>CNSC exemption</th>
<th>CNSC classification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kBq/g or 1 MBq</td>
<td>Class C</td>
</tr>
<tr>
<td>100 Bq/g</td>
<td>Surface contamination free-</td>
</tr>
</tbody>
</table>

### Part 5 – DETECTION AND MEASUREMENT

#### Method of detection (dose rate):
1. Specialized equipment may be required

#### Method of detection (contamination):
1. Hand-held: NaI scintillator, thick ZnS scintillator with proprietary discrimination
3. Non-portable: liquid scintillation counter, NaI well counter

### Dosimetry

- **External:** Gamma/beta
- **Internal:** Whole body counting, Thyroid counting, urinalysis

### Part 6 – SAFETY PRECAUTIONS

- Iodine compound can become volatile. Handle and store in ventilated areas. Iodine can be absorbed through the skin. When iodinated (I-125) albumin injection is heated to decomposition, radioactive fumes containing I-125 may be emitted.
- Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses. Some iodine compounds can penetrate surgical rubber gloves. Wear two pairs of polyethylene gloves over rubber.
- Optimize time, distance, shielding. Use syringe shields and tongs. When possible handle iodine compounds in a fume hood. Use disposable absorbent liners on trays.
- See appendix B for emergency procedures.
Chemical symbol: S
Common name: Sulphur
Atomic weight: 35
Atomic number: 16

Physical half-life: 87.51 days

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Most abundant emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Most energetic emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Shielding information (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma &amp; X-ray</td>
<td>None</td>
<td>None</td>
<td>Not an external radiation hazard</td>
</tr>
<tr>
<td>Beta(-), Beta(+), electrons</td>
<td>167.14 keV (100%)</td>
<td>167.14 keV (100%)</td>
<td>Practical range in glass: 0.2, Practical range in plastic: 0.3</td>
</tr>
</tbody>
</table>

**Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS**

**External dose**
Dose rate to skin from direct contamination: 0.35 mSv/h per kBq/cm² Gamma ray effective dose rate at 1 m: not applicable

**Internal dose**

<table>
<thead>
<tr>
<th></th>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker dose coefficient</td>
<td>7.7E-10 Sv/Bq</td>
<td>1.2E-10 Sv/Bq (organic)</td>
</tr>
<tr>
<td>Worker dose</td>
<td>1.9E-10 Sv/Bq (inorganic)</td>
<td>1.1E-09 Sv/Bq (inorganic)</td>
</tr>
</tbody>
</table>

**Part 4 – CLEARANCE AND EXEMPTION**

<table>
<thead>
<tr>
<th>CNSC exemption</th>
<th>CNSC classification:</th>
<th>Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 kBq/g or 100 MBq</td>
<td>Surface contamination free-release criterion:</td>
<td>100 Bq/cm² (fixed + removable)</td>
</tr>
<tr>
<td>100 Bq/g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Part 5 – DETECTION AND MEASUREMENT**

**Method of detection (dose rate):**
Not applicable

**Method of detection (contamination):**
1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
2. Non-portable: liquid scintillation counter, gas-flow proportional counter

**Dosimetry**

External: Not applicable
Internal: Urinalysis

**Part 6 – SAFETY PRECAUTIONS**

Wear a lab coat and monitor it before leaving the laboratory. Wear appropriate gloves for chemicals handled and wear wrist guards.

S-35 is volatile and should be handled in ventilated enclosures. Take care not to generate sulphur dioxide or hydrogen sulphide, which could be inhaled. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.
Part 1 – RADIONUCLIDE IDENTIFICATION

| Chemical symbol: F | Common name: Fluorine | Atomic weight: 18 | Atomic number: 9 |

Part 2 – RADIATION

Physical half-life: 1.83 hours

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Most abundant emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Most energetic emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Shielding information (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma &amp; X-ray</td>
<td>511.00 keV (194%)</td>
<td>511.00 keV (194%)</td>
<td>Lead: 1\textsuperscript{st} HVL = 7, 2\textsuperscript{nd} HVL = 4.5, 1\textsuperscript{st} TVL = 17, 2\textsuperscript{nd} TVL = 14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Steel: 1\textsuperscript{st} HVL = 36, 2\textsuperscript{nd} HVL = 17, 1\textsuperscript{st} TVL = 72, 2\textsuperscript{nd} TVL = 45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Concrete: 1\textsuperscript{st} HVL = 121, 2\textsuperscript{nd} HVL = 56, 1\textsuperscript{st} TVL = 240, 2\textsuperscript{nd} TVL = 144</td>
</tr>
<tr>
<td>Beta(-), Beta(+), electrons</td>
<td>633.34 keV (100%)</td>
<td>633.34 keV (100%)</td>
<td>Practical range in glass: 0.9 Practical range in plastic: 1.7</td>
</tr>
</tbody>
</table>

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

**External dose**
Dose rate to skin from direct contamination: 1.9 mSv/h per kBq/cm\(^2\) Gamma ray effective dose rate at 1 m: 1.398E-04 mSv/h per MBq

**Internal dose**

<table>
<thead>
<tr>
<th></th>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker dose coefficient</td>
<td>4.9E-11 Sv/Bq</td>
<td>9.3E-11 Sv/Bq</td>
</tr>
</tbody>
</table>

Part 4 – CLEARANCE AND EXEMPTION

<table>
<thead>
<tr>
<th>CNSC exemption</th>
<th>CNSC classification</th>
<th>CNSC unconditional clearance level:</th>
<th>CNSC classification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Bq/g or 1 MBq</td>
<td>Surface contamination free-release criterion: 10 Bq/cm(^2) (fixed + removable)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Bq/g</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part 5 – DETECTION AND MEASUREMENT

**Method of detection (dose rate):**
1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

**Method of detection (contamination):**
2. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

**Dosimetry**
External: Gamma/beta
Internal: Whole body counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses.

Keep handling time to a minimum. Use syringe shields and tongs. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.
Part 1 – RADIONUCLIDE IDENTIFICATION

| Chemical symbol: I | Common name: Iodine | Atomic weight: 123 | Atomic number: 53 |

Part 2 – RADIATION

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Most abundant emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Most energetic emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Shielding information (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma &amp; X-ray</td>
<td>158.97 keV (83.3%), 27.47 keV (46.3%), 27.20 keV (24.8%)</td>
<td>783.59 keV (0.059%), 735.78 keV (0.062%), 687.95 keV (0.027%)</td>
<td>Lead: 1st HVL = 0.06, 2nd HVL = 0.54, 1st TVL = 1.4, 2nd TVL = 12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Steel: 1st HVL = 4.8, 2nd HVL = 8.6, 1st TVL = 24, 2nd TVL = 36</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Concrete: 1st HVL = 59, 2nd HVL = 41, 1st TVL = 145, 2nd TVL = 105</td>
</tr>
<tr>
<td>Beta(-), Beta(+), electrons</td>
<td>127.16 keV (13.7%), 22.70 keV (12.4%), 154.03 keV (1.80%)</td>
<td>506.73 keV (0.012%), 154.03 keV (1.80%), 127.16 keV (13.7%)</td>
<td>Practical range in glass: 0.2 Practical range in plastic: 0.3</td>
</tr>
</tbody>
</table>

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 0.38 mSv/h per kBq/cm²
Gamma ray effective dose rate at 1 m: 2.963E-05 mSv/h per MBq

Internal dose

<table>
<thead>
<tr>
<th></th>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker dose coefficient</td>
<td>2.1E-10 Sv/Bq</td>
<td>2.1E-10 Sv/Bq (vapor)</td>
</tr>
</tbody>
</table>

Part 4 – CLEARANCE AND EXEMPTION

<table>
<thead>
<tr>
<th>CNSC exemption</th>
<th>CNSC classification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Bq/g or 10 MBq</td>
<td>Class C</td>
</tr>
<tr>
<td>100 Bq/g</td>
<td>Surface contamination free-</td>
</tr>
</tbody>
</table>

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
1. Plastic scintillator, ion chamber, ion chamber with window, energy compensated NaI, energy compensated Geiger-Mueller

Method of detection (contamination):
1. Hand-held: NaI scintillator, thick ZnS scintillator with propriety discrimination
3. Non-portable: liquid scintillation counter, gas-flow proportional counter, NaI well counter

Dosimetry
External: Gamma/beta
Internal: Whole body counting, thyroid counting, urinalysis

Part 6 – SAFETY PRECAUTIONS

Iodine compound can become volatile. Handle and store in ventilated areas. Iodine can be absorbed through the skin. Heating sodium iodide 123 capsules to decomposition may emit radioactive fumes containing I-123.

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Also wear safety glasses.

Optimize time, distance, shielding. Syringe shields and tongs should be used. Use disposable absorbent liners on trays. See appendix B for emergency procedures.
Part 1 – RADIONUCLIDE IDENTIFICATION

| Chemical symbol: P | Common name: Phosphorus | Atomic weight: 32 | Atomic number: 15 |

Part 2 – RADIATION

Physical half-life: 14.263 days

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Most abundant emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Most energetic emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Shielding information (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma &amp; X-ray</td>
<td>None</td>
<td>None</td>
<td>Not an external radiation hazard</td>
</tr>
<tr>
<td>Beta(-), Beta(+), electrons</td>
<td>1710.4 keV (100%)</td>
<td>1710.4 keV (100%)</td>
<td>Practical range in glass: 3.4 Practical range in plastic: 6.3</td>
</tr>
</tbody>
</table>

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

External dose

Dose rate to skin from direct contamination: 1.9 mSv/h per kBq/cm² Gamma ray effective dose rate at 1 m: not applicable

Internal dose

<table>
<thead>
<tr>
<th>Worker dose coefficient</th>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.4E-09 Sv/Bq</td>
<td>2.9E-09 Sv/Bq</td>
</tr>
</tbody>
</table>

Part 4 – CLEARANCE AND EXEMPTION

CNSC exemption: 1 kBq/g or 100 kBq
CNSC unconditional: 1 kBq/g
CNSC classification: Class C
Surface contamination free- (fixed + removable): 100 Bq/cm²

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate):
Not applicable

Method of detection (contamination):
1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
2. Non-portable: liquid scintillation counter, gas-flow proportional counter

Dosimetry
External:
Gamma/beta
Internal: Urinalysis

Part 6 – SAFETY PRECAUTIONS

Phosphocol and sodium phosphate (P-32) solutions may emit radioactive fumes containing P-32 when heated to decomposition.

Wear disposable plastic, latex, or rubber gloves. Wear a lab coat, which should be monitored before leaving the laboratory. Wear safety glasses.

Keep handling time to minimum. Plastic syringe shields and tongs can be used to avoid direct skin contact. When possible work behind a plastic screen. Finger dosimeters should be worn if using quantities greater than a few tens of MBq (~a mCi). Use disposable absorbent liners on trays.

See appendix B for emergency procedures.
Part 1 – RADIONUCLIDE IDENTIFICATION

<table>
<thead>
<tr>
<th>Chemical symbol: H</th>
<th>Common name: Tritium</th>
<th>Atomic weight: 3</th>
<th>Atomic number: 1</th>
</tr>
</thead>
</table>

Physical half-life: 12.32 years

Part 2 – RADIATION CHARACTERISTICS

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Most abundant emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Most energetic emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Shielding information (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma &amp; X-rays</td>
<td>None</td>
<td>None</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Beta(-), Beta(+), electrons</td>
<td>18.6 keV (100%)</td>
<td>18.6 keV (100%)</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

External dose

Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS

Tritium is not an external radiation hazard.

Internal dose

Dose coefficients for tritium were obtained from the CNSC’s Health Effects, Dosimetry and Radiological Protection of Tritium INFO- 0799, April 2010.

<table>
<thead>
<tr>
<th>Compound type</th>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker dose coefficient</td>
<td>2.0E-11 Sv/Bq</td>
<td>2.0E-11 Sv/Bq</td>
</tr>
<tr>
<td></td>
<td>2.0E-11 Sv/Bq</td>
<td>2.0E-15 Sv/Bq</td>
</tr>
</tbody>
</table>

Part 4 – CLEARANCE AND EXEMPTION

<table>
<thead>
<tr>
<th>CNSC exemption</th>
<th>CNSC unconditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MBq/g or 1 GBq</td>
<td>100 Bq/g</td>
</tr>
</tbody>
</table>

CNSC classification: Class C
Surface contamination: 100 Bq/cm² (fixed + removable)

Part 5 – DETECTION AND MEASUREMENT

Method of detection (dose rate): Not applicable

Method of detection (contamination):
1. Hand-held: windowless gas-flow proportional
2. Non-portable: liquid scintillation counter

Dosimetry
External: Not applicable
Internal: Urinalysis

Part 6 – SAFETY PRECAUTIONS

Tritium is not a radiation hazard unless it enters the body. Once in the body, tritiated water is uniformly distributed in body water and can then expose tissue. Tritiated water can be absorbed through the surface of the skin, leading to an internal exposure.

Wear a lab coat and polyvinyl chloride (PVC) gloves (0.5 mm thick) because of this material's low permeability to tritiated water. Many tritium compounds readily penetrate gloves and skin. Handle these compounds remotely, wear two pairs of gloves and change the outer layer at least every twenty minutes. Plastic aprons provide added protection, especially against tritiated water. Plastic suits may be necessary for work at TBq levels or in an atmosphere contaminated with tritiated water.

Handle tritiated water, gases and volatile liquids in ventilated enclosures. Use glass containers to store tritium compounds because tritiated water and tritiated organic solvents will permeate through plastic. Use disposable absorbent liners on trays.

See appendix B for emergency procedures.

This page has been printed from the Canadian Nuclear Safety Commission’s (CNSC) Radionuclide Information Booklet. For references to the information provided, consult the booklet available at http://www.nuclearsafety.gc.ca/eng/resources/radiation/radionuclide-information.cfm.
**Part 1 – RADIONUCLIDE IDENTIFICATION**

| Chemical symbol: C | Common name: Carbon | Atomic weight: 14 | Atomic number: 6 |

**Part 2 – RADIATION CHARACTERISTICS**

Physical half-life: 5.73E+03 years

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Most abundant emissions (&gt;10 keV, &gt;0.01%)</th>
<th>Most energetic emissions (&gt;0.01%)</th>
<th>Shielding information (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma &amp; X-rays</td>
<td>None</td>
<td>None</td>
<td>Not an external radiation</td>
</tr>
<tr>
<td>Beta(-), Beta(+) electrons</td>
<td>156.5 keV (100%)</td>
<td>156.5 keV (100%)</td>
<td>Practical range in glass: 0.2 Practical range in plastic: 0.3</td>
</tr>
</tbody>
</table>

**Part 3 – DOSE RATE CONSTANTS AND COEFFICIENTS**

**External dose**

Dose rate to skin from direct contamination: 0.32 mSv/h per kBq/cm² Gamma ray effective dose rate at 1 m: Not applicable

**Internal dose**

<table>
<thead>
<tr>
<th>Worker dose coefficient</th>
<th>Ingestion</th>
<th>Inhalation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.8E-10 Sv/Bq</td>
<td>2.0E-11 Sv/Bq</td>
</tr>
</tbody>
</table>

**Part 4 – CLEARANCE AND EXEMPTION**

- **CNSC exemption quantity:** 10 kBq/g or 10 MBq
- **CNSC classification:** Class C
- **CNSC unconditional:** 1 Bq/g
- **Surface contamination free-** 1 Bq/cm² (fixed + removable)

**Part 5 – DETECTION AND MEASUREMENT**

**Method of detection (dose rate):**

Not applicable

**Method of detection (contamination):**

1. Hand-held: thick ZnS scintillator with proprietary discrimination, gas-flow proportional, sealed-gas proportional, plastic scintillator, halogen quenched thin window Geiger-Mueller
2. Non-portable: liquid scintillation counter, gas-flow proportional counter

**Dosimetry**

- **External:** Not applicable
- **Internal:** Urinalysis, lung, feces

**Part 6 – SAFETY PRECAUTIONS**

Wear disposable lab coat, gloves and wrist guards. Some organic compounds can be absorbed through gloves; wear two pairs and change the outer layer as needed.

Use disposable absorbent liners on trays. Handle potentially volatile or dusty compounds in a fume hood.

See appendix B for emergency procedures.

GLOSSARY

Absorbed Dose
The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the Gray (Gy).

Activity
The number of nuclear disintegrations occurring in a given quantity of material per unit time.

Activity, specific
The activity per unit of mass or volume of a given sample.

ALARA
Acronym for As Low As Reasonably Achievable- making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account technology, the economics of improvements in relation to benefits to the public health and safety, and other socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Alpha Particle
A strongly ionizing particle emitted from the nucleus during radioactive decay, having a mass and charge equal in magnitude to a helium nucleus, consisting of two protons and two neutrons with a double negative charge.

Annual Limit of Intake (ALI)
The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by reference man that would result in a committed effective dose equivalent of 50 mSv or a committed dose equivalent of 500 mSv to any individual organ or tissue.

Background Radiation
Ionizing radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present.

Becquerel
The international (SI) unit of radioactivity in which the number of disintegrations is equal to one disintegration per second.

Beta Particle
Charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Bio Screening
The determination of kinds, quantities or concentrations, and, in some cases, locations of radioactive material in the human body, whether by direct measurement (in vivo) or by analysis and evaluation of materials excreted or removed from the human body.
**Bremsstrahlung**  
Photon radiation produced by deceleration of charged particles (usually electrons) passing through matter

**Calibration**  
Determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors. The check or correction of the accuracy of a measuring instrument to assure proper operational characteristics.

**Contamination, radioactive**  
Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful

**Critical Organ**  
The organ or tissue, the irradiation of which will result in the greatest hazard to the health of the individual

**Decay, radioactive**  
Disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons

**Declared Pregnant Worker**  
A Nuclear Energy Worker who has informed her employer, in writing, of her pregnancy and the estimated date of conception

**Decontamination**  
The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease contamination, (2) letting the material stand so that radioactivity is decreased as a result of natural decay, and (3) covering the contamination to shield or attenuate the radiation emitted.

**Dose Equivalent**  
The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest

**Dose Rate**  
The radiation dose delivered per unit of time

**Dosimeter**  
A portable instrument for measuring and registering the total accumulated exposure to ionizing radiation

**Efficiency (radiation detection instrument)**  
A measure of the probability that a count will be recorded when radiation is incident on a detector

**Electron Volt**  
A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt, abbreviated eV
External Dose
The portion of the dose equivalent received from radiation sources outside the body

Gamma Ray
Very penetrating electromagnetic radiation frequently emitted from the nucleus of an atom during radioactive decay

Geiger-Mueller (G-M) Counter
A radiation detection and measuring instrument consisting of a gas filled tube containing electrodes, between which there is electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted.

Gray
The international (SI) unit of absorbed dose in which the energy is equal to one Joule per kilogram

Half-Life, Biological
Time required to eliminate 50% of a dose of any substance by the regular processes of elimination

Half-Life, Effective
Time required for a radioactive nuclide in a system to be diminished by 50% as a result of the combined action of radioactive decay and biological elimination

Half-Life, Radioactive
Time required for a radioactive substance to lose 50% of its activity by decay. Each radioisotope has a unique half-life

Half Value Layer
The thickness of any specified material necessary to reduce the intensity of an x-ray or gamma ray beam to one-half its original value

Inverse Square Law
The intensity of radiation at any distance from a point source varies inversely as the square of that distance

Ionization
The process by which a neutral atom or molecule acquires a positive or negative charge

Ionizing Radiation
Any radiation capable of displacing electrons from atoms or molecules, thus producing ions

Isotopes
Nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number
Monitoring
The measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses

Neutron
Elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral

NORM
naturally occurring radioactive materials

Occupational Radiation Dose
The dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.

Photon
A quantum of energy emitted in the form of electromagnetic radiation. Gamma rays and x-rays are examples of photons

Principal Investigator (P.I.)
A faculty member appointed by the licensee, who has been approved through the Radiation Safety Committee for the purchase and use of radioactive materials

Proton
An elementary nuclear particle with a positive electric charge located in the nucleus of an atom

Quality Factor
A modifying factor that is used to derive dose equivalent from absorbed dose. It corrects for varying risk potential due to the type of radiation

Radioisotope
A nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

Radiosensitivity
The relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of radiation

Radiotoxicity
Term referring to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body
**Scintillation Counter**
A counter in which light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photomultiplier tube

**Sealed Source**
Radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions which are likely to be encountered in normal use and handling

**Sievert**
The international (SI) of dose equivalent

**Thermoluminescent Dosimeter (TLD)**
Crystalline materials that emit light if they are heated after they have been exposed to radiation
## A CHRONOLOGY OF RADIATION PROTECTION

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1895</td>
<td>Roentgen discovers x-rays</td>
</tr>
<tr>
<td>1896</td>
<td>Becquerel discovers nuclear radiation</td>
</tr>
<tr>
<td>1898</td>
<td>Discovery of radioactivity by Marie &amp; Pierre Curie</td>
</tr>
<tr>
<td>1899</td>
<td>Rutherford recognizes three types of nuclear radiation</td>
</tr>
<tr>
<td>1900</td>
<td>American Roentgen Ray Society (ARRS) founded</td>
</tr>
<tr>
<td>1902</td>
<td>First proposal to limit exposure</td>
</tr>
<tr>
<td>1913</td>
<td>First radiotracer experiment</td>
</tr>
<tr>
<td>1915</td>
<td>British Roentgen Society adopted x-ray protection resolution;</td>
</tr>
<tr>
<td>1920</td>
<td>ARRS established standing committee for radiation protection</td>
</tr>
<tr>
<td>1921</td>
<td>British X-ray &amp; Radium Protection Committee presented its first radiation protection rules</td>
</tr>
<tr>
<td>1922</td>
<td>American Registry of X-Ray Technicians founded</td>
</tr>
<tr>
<td>1925</td>
<td>Specific skin dose limit proposed</td>
</tr>
<tr>
<td>1925</td>
<td>First International Congress of Radiology, London, established ICRU</td>
</tr>
<tr>
<td>1927</td>
<td>Demonstration of the genetic effects of radiation</td>
</tr>
<tr>
<td>1928</td>
<td>ICRP established under the auspices of the Second International Congress of radiology, Stockholm</td>
</tr>
<tr>
<td>1928</td>
<td>ICRU adopted the Roentgen as the unit of exposure</td>
</tr>
<tr>
<td>1929</td>
<td>Advisory Committee on X-ray and Radium Protection (ACXRP) formed in the US, a forerunner of NCRP</td>
</tr>
<tr>
<td>1931</td>
<td>ACXRP published recommendations (National Bureau of Standards Handbook 15)</td>
</tr>
<tr>
<td>1934</td>
<td>ICRP recommended a daily tolerance dose</td>
</tr>
<tr>
<td>1936</td>
<td>Reduction of limit to 0.1 R/day</td>
</tr>
<tr>
<td>1941</td>
<td>ACXRP recommended first permissible body burden, for radium</td>
</tr>
<tr>
<td>1942</td>
<td>Manhattan project began to develop atomic bomb</td>
</tr>
<tr>
<td>1942</td>
<td>Birth of Health Physics as a profession</td>
</tr>
<tr>
<td>1946</td>
<td>U.S. Atomic Energy Commission (AEC) created</td>
</tr>
</tbody>
</table>
1946  NCRP formed
1947  U.S. National Academy of Sciences established Atomic Bomb Casualty Commission (ABCC) to study the long term effects on A-bomb survivors in Hiroshima and Nagasaki
1949  NCRP recommended and introduced risk/benefit concept
1953  ICRU introduced the concept of absorbed dose
1955  Health Physics Society formed
1955  United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) established
1956  International Atomic Energy Agency (IAEA) organized by the United Nations
1956  Reduction of annual occupational exposure limit to 5 R/year
1957  NCRP introduced age proration for occupational doses and recommended non-occupational exposure limits
1959  Introduction of Quality Factor (QF) and Linear Energy Transfer (LET) basis
1964  International Radiation Protection (IRPA) formed
1969  Radiation on space - man landed on moon
1975  International adoption of SI units, (Gy, Sv, Bq)
1978  ICRP 30 - *Limits for Intakes of Radionuclides by Workers*
1978  ICRP adopted *effective dose equivalent* terminology
1987  NCRP 91 - *Recommendations on Limits for Exposure to Ionizing Radiation*
1991  ICRP 60 - *1990 Recommendations of the International Commission on Radiological Protection*
1993  NCRP 115 - *Risk Estimates for Radiation Protection*
1993  NCRP 116 - *Limitation of Exposure to Ionizing Radiation*
1997  Canadian Parliament adopted the *Nuclear Safety & Control Act*
2000  The *Nuclear Safety & Control Act* came into force enabling the launch of the CNSC
REFERENCES


IAEA Safety Series, No. 38 - Radiation Protection Procedures

NCRP Report No. 8 - Control and Removal of Radioactive Contamination in Laboratories

NCRP Report No. 65 - Management of Persons Accidentally Contaminated with Radionuclides


Dalhousie University - Radiation Safety Program, Policy & Procedure Manual

Dalhousie University - Radiation Safety Policies

ACRP/CCRP - ACRP - 20, Radiation Safety Officers Handbook

University of Madison, Wisconsin, Radiation Safety Training Manual

University of Florida, Radiation Safety Short Course Study Guide

University of Michigan web site, http://www.umich.edu/group/eih/UMSCHPS

Multiple Exposures, Catherine Caulfield