Radiation Safety Training Manual

All new staff are expected to become familiar with the material in this document. Please review, date and sign to confirm that you have read the material.

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Telephone Contact Information

Radiation Incidents

Radiation Safety Officer       Melissa Michaud       494-1938 (Office)
                                403-3063 (Cell)
Director of EH&S               Raymond Ilson         494-2495/1241 (Office)
After Hours                    Security             4109

Emergency Numbers

EMERGENCIES
Dalhousie Security      494-6400
Dalhousie Health Service 494-2171
Poison Control          428-8161
Dalhousie Maintenance   494-3345
                          494-6400 (after hours)

Members of the Radiation Safety Committee (2011)

Dr. A. Chatt           494-2474
Dr. S. Cameron        494-3759
Dr. R. Dunlap         494-2394
Dr. K. Hall           494-2679
Dr. K. Hewitt         494-7109
Dr. D. Hoskin (Chair) 494-6509
Mr. R. Ilson          494-2495/1241
Ms. K. Murphy         494-8001
Dr. N. Ridgway        494-7133
Ms. M. Michaud (Secretary) 494-1938
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Section 1 - Introduction

CANADIAN 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 The legislation replaced the outdated Atomic Energy Control Act and paved the way for the creation of the Canadian Nuclear Safety Commission (CNSC).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:

a) prevent unreasonable risk to the environment or to the health and safety of the public
b) prevent unreasonable risk to national security
c) achieve compliance with international treaties and obligations on the peaceful use of nuclear energy
d) 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>
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<tbody>
<tr>
<td><strong>Health</strong></td>
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<tr>
<td>Smoking (20 cigs/day)</td>
<td>6 years</td>
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<tr>
<td>Overweight (15%)</td>
<td>2 years</td>
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<tr>
<td>Alcohol (Canadian average)</td>
<td>1 year</td>
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<tr>
<td>All accidents</td>
<td>207 days</td>
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<tr>
<td>All natural hazards</td>
<td>7 days</td>
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<tr>
<td>Occupational Exposure (&lt; 3 mSv/yr)</td>
<td>15 days</td>
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<tr>
<td><strong>Industry</strong></td>
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<tr>
<td>All industries</td>
<td>60 days</td>
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<tr>
<td>Agriculture</td>
<td>320 days</td>
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<tr>
<td>Construction</td>
<td>227 days</td>
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<tr>
<td>Mining</td>
<td>167 days</td>
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<tr>
<td>Manufacturing</td>
<td>40 days</td>
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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)
RADIATION AND THE WORLD WE LIVE IN

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>
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<tbody>
<tr>
<td>Radio Waves</td>
<td>X-Rays</td>
<td>Alpha Particles (α)</td>
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<tr>
<td>Microwaves</td>
<td>Gamma Rays</td>
<td>Beta Particles (β)</td>
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<td>Infrared (heat)</td>
<td>Cosmic Rays</td>
<td>Neutrons</td>
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<td>Visible light (color)</td>
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<td>Ultra-violet</td>
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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-rem/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.
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:

a) cellular repair capability
b) linear energy transfer (LET) for the particular radiation
c) synergistic effects from other metabolic processes
d) delivery rate of the dose

Alterations in 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:

a) embryonic tissue  
b) hematopoietic organs  
c) gonads  
d) epidermis  
e) intestinal mucous membrane  
f) connective tissue  
g) muscle tissue  
h) 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:

a) **Somatic effects:** effects occurring in the exposed individual that may be divided into two classes.
   1. Prompt effects - observable soon after a large dose, >1 Sv to the whole body
   2. Delayed effects - may occur years after an exposure

b) **Genetic effects:** abnormalities passed on to future generations as a result of a parent's exposure

c) **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 in-coordination, 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.

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

<table>
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<tr>
<th>Organ/Tissue</th>
<th>Millisieverts/year ( mSv/yr )</th>
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<tbody>
<tr>
<td>Whole body</td>
<td>1</td>
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<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 Are The Hazards Associated With Ionizing Radiation?

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

- external radiation exposure
- skin contamination and/or deposition in the body (internal exposure)
- spread of contamination

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.
WORKING SAFELY - RESPONSIBILITIES

Principal Investigators:

1. to ensure that the conditions stated in the permit are fulfilled and that safe laboratory practices are followed.
2. to ensure that all staff using nuclear substances have been authorized to use the materials.
3. to ensure that all staff using nuclear substances have been issued (if required), and use, a TLD and participate in bioassay programs if required.
4. to designate specific work and storage areas for nuclear substances and to ensure that these areas are kept clean, are properly labeled, have adequate ventilation, and are adequately shielded.
5. to ensure that staff using nuclear substances receive adequate radiation safety training from the institution and have been informed of the risks associated with exposure to ionizing radiation.
6. to ensure that functional instrumentation is available to monitor exposure and contamination.
7. to maintain records of all nuclear substances as well as storage and disposal records
8. to maintain all monitoring & wipe test records.
9. to report all radiation incidents to the RSO

Users:

1. become familiar and comply with your institutions and any local lab safety regulations
2. work in such a manner as to minimize exposure to yourself and your fellow workers
3. report to your supervisor any incident involving a known or suspected exposure, personal contamination or a spill exceeding maximum permissible limits.
4. carry out regular contamination checks and clean up any contamination
5. a female employee must make herself familiar with the Prenatal Exposure Policy see Section 7
The Workplace

Laboratory Procedures:

- Careful Planning
- Safe Work Habits
- Routine Monitoring & Record Keeping
- Proper Disposal of Radioactive Waste
- Consultation with Radiation Safety Staff

A: Careful Planning:

a) 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)

b) Ensure that your lab is approved for the nuclear substance you wish to use

c) Determine the requirements for personal monitors, survey equipment and shielding.
   - whole body monitoring (TLD)
   - extremity monitoring (ring TLD)
   - bioassay
   - survey meter with GM detector
   - survey meter with NaI detector
   - lead vs plexiglass shielding

B: Safe Work Habits:

a) Do not bring unnecessary personal items into the laboratory.

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

c) Follow the correct procedure for the receipt of a radioactive shipment.

d) Have fume hood flow rates checked. Flow rate should be between 0.5 - 1.0 m/sec.

e) 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

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

g) **Cleanliness** and **good housekeeping** are the most effective elements of proper operating technique.

h) To control the hazard from external radiation the following three principles are applied:

**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

**C: Routine Monitoring & Record Keeping**

Hands, clothing and work areas must be monitored with an appropriate survey instrument at least as often as required by the CNSC. Individual institutions may require more stringent monitoring requirements. At Dalhousie we require that you do a direct survey with an appropriate survey meter on a daily basis when using $^{32}$P or a gamma emitter. Wipe testing is required on a weekly basis for any nuclear substance use including the above. **Records of all such surveys must be maintained and available for inspection at any time.**

**Direct Survey Method:**

This method is suitable for most gamma emitters as well as high energy beta emitters such as $^{32}$P. Choose a suitable instrument and pass the probe slowly over the area to be monitored taking care that the probe does not come in contact with the surface being monitored.
**Survey Meters:**

The type of radiation survey instrument most often used for monitoring of beta and gamma radiation is a Geiger-Mueller tube connected to a count rate meter with a scale reading most commonly in cpm. No one survey meter will have all of the characteristics which might be desired, so it is important to select the proper instrument for your particular monitoring situation. Further, it is necessary to know how to use that instrument intelligently and to be able to interpret the results.

The purpose of your instrument is twofold - to keep a constant surveillance over the working environment and to detect the quantity and extent of contamination.

**Routine Performance Checks of Survey Meters:**

For instruments with needle indicators *before each use*:

a) Inspect the instrument carefully
   - Are there indications it may have been dropped?
   - Is anything damaged on it?
   - If the detector is used as a probe, does the cable show signs of breakage?
   - Is the meter free of contamination?
   - Is the needle in the zero position?
   - Does the needle bounce around excessively when the meter is moved?

a) Turn the instrument on and allow it to warm up. If the meter was already on it may be that the last user forgot to turn it off. Do the batteries need replacing?

b) **Turn to the battery check position and see that the batteries are good.**

c) Turn the range selector knob to the highest scale and let the needle stabilize. Continue turning to more sensitive scales until a response is obtained. The needle will fluctuate more on the lower scales because of the random nature of the detected events.

d) Check the response of the meter on each operational scale with a radiation check source that gives a reading close to mid-scale. Repeat three times to test reproducibility. The readings should not deviate from the value by more than 10%.

e) Have the instrument calibrated annually, if required by CNSC=s document *R-117 Requirements for Gamma Radiation Survey Meter Calibration.*
When You Should Use The Survey Meter:

a) The survey meter should be switched on during your procedure whenever radioactivity is involved so that any unexpected release of radioactivity can be detected immediately. Hands should be monitored frequently so that contaminated gloves can be changed.

b) Survey meters should always be used when receiving and unpacking radioactive packages.

c) At the end of the day, where appropriate, monitor your work area.

d) Each week monitor the entire area for any undetected contamination. If counts more than twice background are detected, a wipe test of the area should be done and the wipe measured to determine if the contamination is loose or fixed.

e) The survey meter should be used during a radioactive spill clean up procedure to assess the progress of the decontamination procedure.

f) The survey meter can be used as a personal monitor to survey hands, lab coat and footwear prior to leaving the lab.

Survey Procedure:

a) Select a suitable survey instrument for your needs (e.g. GM probe is only 0.01 - 0.05 % efficient for $^{125}$I whereas a low energy scintillation probe has a greater than 20 % efficiency).

b) Pass the probe slowly over the area to be monitored taking care that the probe does not come into direct contact with the surface being monitored.

c) If the meter needle reads off scale, gently turn the range selection knob to a higher scale.

d) Record results and clean any contaminated areas.

e) Make sure that the audible response for your meter is switched on in advance. Audible response is much faster than visual needle response. Survey meters may under respond in a high radiation field.

Indirect Survey Method (Wipe Test)

a) Prepare a floor plan of the lab.

b) Mark locations to be tested - include benches, floor areas, fume hoods, disposal sinks, equipment, telephone receivers, incubators etc.

c) Using a Q-Tip, filter paper etc., moistened with a suitable solvent (water, alcohol) wipe a representative area (100 sq. cm.). Use one wipe per location.

d) Allow to air dry.

e) Place in an appropriate container for counting.

f) Measure the activity with an appropriate instrument.

g) Do a background count using a clean wipe.

h) Record results.
Remember that the wipe test efficiency for a wet wipe is only about 10% and 1% for a dry wipe

General Laboratory Rules

1. Wear proper protective clothing. Suitable gloves must be worn. Double gloving is always recommended. Lab coats are to be worn. Shoe covers and eye protection may be needed in some instances. Bare legs and open toed shoes are not acceptable. Protective clothing must not be taken out of the local areas in which their use is required unless monitored and determined free of contamination.

2. Local rules will define what dosimeters are to be worn, (e.g., extremity TLD, DRD). These devices are to be worn on the trunk (with the exception of extremity TLD=s), between waist & shoulder level, the location representative of the highest exposure rates to which the body is subjected. If the hands are exposed to significantly higher levels than the rest of the body because of close work with localized sources (kBq amounts of high specific activity P-32 in Eppendorf tubes), a separate finger dosimeter should be worn. To be effective, personal monitoring devices must always be worn by the worker when he/she is occupationally exposed and must not be exposed to radiation when not on the worker or if the worker is undergoing an x-ray or Nuclear Medicine procedure.

3. Participate in bioassay programs if required. Refer to Section 7, Radiation Safety Policies.

4. Do not pipet by mouth.

5. Hazardous operations are not to be performed alone (radioiodinations).

6. Do not eat drink, smoke, store food or apply cosmetics in a nuclear substance laboratory.

7. Monitor and clean work areas as often as required by permit or licence conditions.

8. Wear safety glasses when working with high energy beta emitters or if a chemical hazard is present.

9. Have a suitable survey instrument available and turned on.

10. Double contain and work on lined spill trays. Any material which may give rise to airborne contamination must be confined to a fume hood or glove box - radioiodine during a radioiodination, $^{35}$S amino acids, and airborne particles when scraping TLC plates.

11. Label anything likely to become radioactive.

12. Promptly return stock solutions to storage areas.

13. Promptly decontaminate glassware.

14. Monitor hands, clothing and footwear before leaving the laboratory.

15. Use the minimum quantity of radioactive material needed for the investigation. Disposal of all radioactive waste is subject to regulatory 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 AGuidelines 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:

a) identify source characteristics

b) preplan your experiment

c) have available and wear personal protective equipment (PPE)

d) 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

e) 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

f) to prevent unauthorized removal, label containers and equipment with the following information
   - nuclear substance
   - date
   - activity
   - user
Means to Limit Contamination:

**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 ($\checkmark$), positive results must be noted with follow up action taken.

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

$^{35}$S, $^{14}$C $\sim 10\%$

Surface Monitoring

Personal Monitoring
VIDEO PRESENTATION

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>
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</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. Not immediate

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

4. Generally specific

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

5. Accuracy depends on

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

6. Alternative to using LS 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**

\[
Bq/cm^2 = CPM\ text{net}\ [C.E. \times 60 \times 100 \times W_{eff}]
\]

Where: \( Bq/cm^2 \) = Becquerel per centimeter squared  
C.E. = counting efficiency  
60 = 60 seconds  
100 = area of 100 cm\(^2\) 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

____________________________________________________________________________________
____________________________________________________________________________________
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____________________________________________________________________________________
____________________________________________________________________________________

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 thorough documentation
   ____________________________
   ____________________________

8. Interpret results
   ____________________________
   ____________________________

YOU ARE THE KEY TO CONTAMINATION CONTROL !!
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 cleanup 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.**
DALHOUSIE UNIVERSITY

RADIOACTIVE SPILL CLEAN-UP PROCEDURE

1. Preparation Steps

Assemble at least one decontamination kit for each radioisotope laboratory. Items to be included in each kit are as follows:

- radioactive warning signs and tape
- disposable gloves
- small and large plastic bags
- masking tape
- grease pencil
- forceps/tongs
- gauze sponges
- decontamination detergent
- commercial scouring powder
- identification tags
- filter paper wipes
- scissors
- disposable absorbent pads
- floor plan

Include personal decontamination items as follows:

- sponge
- nail brush
- bar soap
- box tissues
- paper towels

2. 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.

5. Start area decontamination under qualified supervision. Inexperienced personnel should not attempt unsupervised decontamination.
3. **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>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>
Dalhousie University

RADIATION INCIDENT REPORT

To: Radiation Safety Office

From: __________________________       __________________________

Principal Investigator       Signature

Date: __________________________

Location Of Incident: __________________________       __________________________

Building       Room #

Nuclear Substance(s) Involved: __________________________       Estimated Activity: _______

Date/Time Of Incident: __________________________/________________________

Date       Time

Name Of Person Making Report: __________________________

Instrument Used To Check For Contamination: __________________________

5. Give a brief description of the incident:

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

6. Name of individual(s) present:

_______________________________________________________________________________

7. Injuries sustained: ________ (yes) ________ (no)

8. Personnel contamination: ________ (yes) (describe) ________ (no)

_______________________________________________________________________________

_______________________________________________________________________________

9. Action Taken: (see attached report)

10. Statement Of The Cause(s):
11. Any Remedial Action Taken:

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

12. 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>
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<tbody>
<tr>
<td></td>
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</table>

Name:___________________________________

Radiation Safety Training Manual 2011 53
Section 7 – Radiation Safety Policies

ALARA STATEMENT

ALARA, an acronym for 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 licence activity is undertaken, taking into account 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, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licence materials in the public interest.

The current system of radiological protection reflected in the International Commission on Radiological Protection (ICRP) Publication 60, 1990 Recommendations of the International Commission on Radiological Protection, and the National Council on Radiological Protection (NCRP) Publication 116, Limitation of Exposure to Ionizing Radiation, is based on three general criteria:

1) **Justification**, the need to justify any activity which involves radiation exposure on the basis that the expected benefits to society exceed the overall societal detriments

2) **Optimization**, the need to ensure that the benefits of such justifiable activities or practices is maximized for the minimum associated societal detriment, economic and social factors being taken into account

3) **Dose and Risk Limitation**, the need to apply dose limits to ensure that individuals or groups of individuals do not exceed acceptable levels of risk.

Dalhousie University is committed to maintaining radiation exposures to staff, students, and the public, resulting from the use of radioisotopes and radiation emitting devices in diagnostic, therapeutic and research procedures, as low as is reasonably achievable, ALARA. The Radiation Safety Committee and the Radiation Safety Office will advise and assist in all matters of radiation safety. The Committee will recommend to University administration through the Radiation Safety Office, policies and procedures to be required for maintaining radiation exposures ALARA through the 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.

Sources of radiation include materials or equipment which are capable of emitting ionizing radiation. Ionizing radiation sources include radioactive materials, nuclear reactors, particle accelerators, x-ray machines and electron microscopes.

Policies and procedures for radiation safety are delineated in the Dalhousie University, Radiation Safety Manual.
Introduction:

**ALARA** an acronym for **As Low As Reasonably Achievable**, means making 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, taking into account the state of technology, the economics of improvements in relation to the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licenced materials in the public interest.


I. **Justification** - the need to justify any activity which involves radiation exposure on the basis that the expected benefits to society exceed the overall societal detriments

II. **Optimization** - the need to ensure that the benefits of such justifiable activities or practices is maximized for the minimum associated societal detriment, economic and social factors being taken into account

III. **Dose and Risk Limitation** - the need to apply dose limits to ensure that individuals or groups of individuals do not exceed acceptable levels of risk

Administration Commitment:

a) The administration of Dalhousie University is committed to the program described herein for keeping individual and collective doses as low as reasonably achievable. In accord with this commitment we hereby describe an administrative organization for radiation protection and will develop policies, procedures and instructions to foster the **ALARA** concept. The organization will be comprised of a Radiation Safety Committee and a Radiation Safety Officer (RSO).

b) An annual review of the radiation safety program will be performed. This review will include operating procedures, past personnel dose records, inspections, laboratory self-audits, training and consultation with the RSO.

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, in our judgement, is considered unjustified. If modifications have been recommended but not implemented, we will be prepared to justify the reasons for not implementing them.

d) The Radiation Safety Committee will meet quarterly to review the **ALARA** program with a formal written annual report submitted no later than one month after the end of the calendar year.
**Obligations of Licensees**

1. Ensure the presence of a sufficient number of qualified workers to carry on the licensed activity safely and in accordance with the Nuclear Safety and Control Act (the Act), the regulations made under the Act and the Nuclear Substances and Radiation Devices Licence.

2. Train workers to carry on the licensed activity in accordance with the Act and regulations.

3. Take all reasonable precautions to protect the environment and the health and safety of persons and to maintain security.

4. Provide the devices required by the Act and regulations and maintain them within the manufacturer=s specifications.

5. Require that every person at the site of the licensed activity uses equipment, devices, clothing and procedures in accordance with the Act and regulations.

6. 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.

7. 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.

8. Implement measures for alerting the licensee to acts of sabotage or attempted sabotage anywhere at the site of the licensed activity.

9. Instruct the workers on the physical security program at the site of the licensed activity and to their obligations under that program.

10. 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.

These obligations are tasked to the Radiation Safety Committee to be carried out by the Radiation Safety Officer.

**Obligations of Workers:**

a) 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 (permit).

b) 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) Promptly inform the licensee or the worker’s supervisor of any situation in which the worker believes there may be

i) A significant increase in the risk to the environment or the health and safety of persons

ii) A threat to the maintenance of security or a incident with respect to security

iii) A failure to comply with the Act, the regulations made under the Act or the permit

iv) An act of sabotage, theft, loss or illegal use or possession of a nuclear substance, prescribed information, or

v) A release into the environment of a quantity of a radioactive nuclear substance or hazardous substance that has not been authorized by the licensee

- Observe and obey all notices and warning signs posted by the licensee in accordance with the Radiation Protection Regulations, and

- 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.

**ALAR A Procedures:**

The Radiation Safety Committee will delegate authority to the RSO for enforcement of these procedures. The Radiation Safety Committee will support the RSO when necessary in asserting his/her authority. If the Radiation Safety Committee overrules the RSO, it will record the basis for its action in the minutes of the quarterly meeting.

a) 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 on the EH&S web site at [http://safety.dal.ca](http://safety.dal.ca)

b) All new occupationally exposed workers will participate in the first available Radiation Safety Training course available after joining a research group, unless otherwise exempted by the RSO. The Radiation Safety Training course is held three times annually, typically in May, September and December.

c) The RSO will thoroughly review the qualifications of each principal investigator 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.

d) The RSO will thoroughly review all planned laboratory construction and renovation prior to submission of plans to the Canadian Nuclear Safety Commission (CNSC) to ensure that the requirements of CNSC’s Regulatory Document R-52 Design Guide for Basic and Intermediate Level Radioisotope Laboratories@ are met.

e) The RSO will review quarterly the occupational radiation exposures of all monitored workers. Dalhousie University does not have any Nuclear Energy Workers (NEW), therefore the limits set for a person who is not a nuclear energy worker@ apply. An action level of one third the maximum limit is set. If an action level is exceeded the RSO will conduct an investigation and decide if action is warranted. These limits apply to combined external and internal exposures.
<table>
<thead>
<tr>
<th>Item</th>
<th>Person</th>
<th>Period</th>
<th>Effective Dose (mSv)</th>
<th>Action Level (mSv)/quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a person who is not a NEW</td>
<td>1 calendar year</td>
<td>1 mSv</td>
<td>0.3 mSv</td>
</tr>
<tr>
<td>2</td>
<td>a person who is not a NEW lens of an eye</td>
<td>1 calendar year</td>
<td>15 mSv</td>
<td>5 mSv</td>
</tr>
<tr>
<td>3</td>
<td>a person who is not a NEW skin</td>
<td>1 calendar year</td>
<td>50 mSv</td>
<td>16 mSv</td>
</tr>
<tr>
<td>4</td>
<td>a person who is not a NEW hands &amp; feet</td>
<td>1 calendar year</td>
<td>50 mSv</td>
<td>16 mSv</td>
</tr>
</tbody>
</table>

f) Licence 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 emit beta or gamma radiation
- **Class C** - typically short lived and emit beta and gamma radiation

At Dalhousie University Class B & C radionuclides are typically used. In keeping with an ALARA policy 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 cm².

<table>
<thead>
<tr>
<th>Class</th>
<th>Control Area Limit</th>
<th>Public Area/Decommissioning Limit</th>
<th>Dalhousie 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>3.0 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>

g) Apply the **Compliance Enforcement Policy** as required

h) Each research group will be required to conduct a nuclear substance laboratory self-audit on a twice yearly basis, in May and November. These audits will be reviewed by the RSO and appropriate corrective action taken within one week of receipt of audit.
COMPLIANCE ENFORCEMENT POLICY
DALHOUSIE UNIVERSITY

Introduction:

Dalhousie University is issued a Nuclear Substances and Radiation Devices Licence by the Canadian Nuclear Safety Commission (CNSC) for the possession, use and importation of nuclear substances or devices containing nuclear substances.

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 who are primarily in one location. 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 Safety Series 6 Regulations for the Safe Transport of Radioactive Material, 1985 edition (as amended 1990), as well as conditions that apply to the licence.

The CNSC requires the following three components are in place:
1. Radiation Safety Committee
2. Radiation Safety Officer

Although the Radiation Safety Officer is responsible for the day to day operations of the radiation safety program he/she reports to the Radiation Safety Committee which has the authority to implement and enforce the radiation safety program encompassing the use, handling, storage and disposal of nuclear substances. The Radiation Safety Committee is appointed by and accountable to the Vice-President, Academic and Research.

The institution is visited annually by compliance inspectors from the CNSC to ensure that the above regulations and 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.

COMPLIANCE AUDIT POLICY

The Radiation Safety Officer will visit each lab to which a nuclear substance user permit is issued, at a minimum annually. The visit will be unannounced. A compliance check list approved by the Radiation Safety Committee will be used. Violations 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 would include:

- contamination above license criteria
- inadequate monitoring program
- use or storage of food or drink in the laboratory
- inadequate training of new staff
- non-participation in required bioassay programs
- refusal to wear required PPE (personal protective equipment)
- inadequate security measures to safeguard nuclear substances
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 signage  
b) inadequate posting (permit, AECB posters)  
c) inadequate inventory records  
d) inappropriate use of warning labels  
e) failure to wear required PPE

**MAJOR OFFENCE ACTIONS**

1. On the first occurrence written 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 Radiation Safety Committee. 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 Radiation Safety Office.

For the second or third occurrences notification of the above actions will be copied to the department head and the Dean.

**MINOR OFFENCE ACTIONS**

1. On the first occurrence, the permit holder will be notified verbally by the Radiation Safety Officer of the violation observed.

2. On a second occurrence within a twelve month period the Radiation Safety Officer will send written notification of the observed violation to the permit holder, with copies to the department head and the Radiation Safety Committee.

3. On a third occurrence, within a twelve month period the Radiation Safety Officer 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 Radiation Safety Committee 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.
Bioassay Requirements

Introduction:

Bioassay is defined as the determination of kinds, quantities, or concentrations, and in some cases, locations of radioactive material in the human body, whether by direct (in vivo) measurement or by analysis and evaluation of radioactive materials excreted or removed from the human body (in-vitro). Examples of bioassay are:

11. Direct counting of the whole body or portions of the body (neck for $^{125}$I) using external detectors

12. Measurement of nuclear substances in urine, faeces, blood or sputum using either a gamma counter or liquid scintillation counting.

The CNSC requires:

1. Under condition 9 of our licence

   *Every person who*

   a) uses at a single time a quantity of volatile iodine-125 or iodine-131 exceeding;

   1. 5 MBq in an open room;
   2. 50 MBq in a fume hood;
   3. 500 MBq in a glove box;
   4. any other quantity in other containment approved in writing by the Commission or a person authorized by the Commission; or

   1. is involved in a spill of greater than 5 MBq of volatile iodine-125 or iodine-131;
   2. or on whom iodine-125 or iodine-131 external contamination is detected; and shall, undergo thyroid screening within five days following the exposure of iodine-125 or iodine-131.

Under condition 10 of our licence

*Screening for internal 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-125 or iodine-131; or
   a bioassay procedure approved by the Commission or a person authorized by the Commission.

Under condition 11 of our licence

*If thyroid screening detects more than 10 kBq of iodine-125 or iodine-131 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 licensed by the Commission to provide internal dosimetry.*
Procedure:

1. The Radiation Safety Office shall be notified 24 hours in advance of a radio-iodination.

b) Items c, d, e, and f of the Nuclear Substance User permit Special Conditions shall be strictly adhered to.

c) Personnel shall report to the Radiation Safety Office with 48 hours of the radio-iodination for routine thyroid screening if amounts of iodine-125 or iodine-131 meet or exceed those limits as referenced in condition 9 of the university consolidated licence.

d) Personnel must report any spill or external personal contamination to the Radiation Safety Office immediately.

Currently no Dalhousie University labs are performing radioiodinations with amounts of radioactivity that would require thyroid screening. The above procedure will be implemented at such time that it would be required.
Prenatal Radiation Exposure Policy

**Introduction:**

Every pregnant woman and her developing fetus are exposed to some risks affecting their well being. These risks may be voluntary or involuntary and avoidable or unavoidable on the part of the mother. They include the ingestion of alcohol, tobacco smoke, prescription and non-prescription drugs, dietary and environmental agents and exposure to ionizing radiation from non-medical sources.

In utero radiation exposure of the embryo causes intense anxiety among parents and the public in general. Too often, pregnant women and their families are frightened by careless statements made with little or no regard of the actual facts.

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

The fetus passes through three relatively clear cut phases. In each of which the type and magnitude of an effect that can be produced by radiation will differ. They are:

**Preimplantation**

This period begins with fertilization and ends with implantation in the uterus. This stage is complete at 10 days. There are few epidemiologic data available for this period of gestation. During preimplantation, irradiation of animals appears to lead to all or none effects. X-ray doses of 2 Gy in mice result in a high incidence of embryonic death; however, those that survive appear to be normal. It is possible that spontaneous abortions increase slightly during this early time period; however, this increase has been too small to quantitate accurately. The normal incidence of spontaneous abortion in humans may be as high as 30-50%.

**Organogenesis**

The period of organogenesis is usually divided into early and late portions. The early organogenesis period is 15-28 days after conception, whereas late organogenesis refers to the time 29-50 days after conception. During early organogenesis, the embryo is sensitive to lethal, teratogenic and growth-retarding effects because of the criticality of cellular activities and the high proportion of radiosensitive cells. Irradiation at this time may lead to severe developmental defects. Effects in animals can be seen down to 100 mSv. Human embryos exposed to similar doses at Hiroshima and Nagasaki, however, did not exhibit any increase in frequency of developmental defects.

**Fetal Stage**

Animal experiments suggest that irradiation is less likely to lead to developmental anomalies after the first two months of gestation. The only human data available are drawn from pregnant survivors of Hiroshima and Nagasaki, where reduced head size and mental retardation were the developmental abnormalities noted after whole body exposures exceeding 500 mSv. There is also thought to be an increased risk of childhood cancer. The natural incidence of childhood cancer including leukemia, up to the age of ten years is 6 per 10,000. The added risk of cancer including leukemia from exposure during pregnancy is 2-6 per 10,000 per 10 mSv over the first ten years of life. The best estimate of risks associated with prenatal exposure to radiation suggests that the overall risk lies in the range of 0-1 cases per 1000 irradiated by 10 mSv in utero, which is at least 30 times lower than the natural level of occurrence of serious handicaps in average pregnancies.
The vast majority of occupationally exposed radiation workers at Dalhousie University receive annual whole body exposures of less than 1 mSv.

**Fetal Exposure and the Nuclear Safety and Control Act:**

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 and enforced locally by the Dalhousie University Radiation Safety Committee. The Nuclear Safety and Control Act requires that the dose to the pregnant Nuclear Energy Worker after the licensee is informed of the pregnancy of that worker shall not exceed 4 mSv. The vast majority of occupationally exposed radiation workers at this institution receive annual whole body exposures of less than 1 mSv. Thus a pregnant worker exposed to the levels of radiation which would normally be encountered at Dalhousie is well within the levels of radiation exposure as defined in the Nuclear Safety and Control Act and the probability of harm occurring to the fetus is considered to be extremely small in comparison to the incidence of spontaneous genetic and developmental abnormalities.

**On March 20, 1997 the federal Nuclear Safety and Control Act received Royal Assent. The new act replaces the 50 year old Atomic Energy Control Act.**

**RESPONSIBILITIES OF FEMALE RADIATION WORKERS:**

a. Where a pregnant nuclear energy worker becomes aware of her pregnancy, she shall immediately inform Dalhousie University in writing of her pregnancy.

**RESPONSIBILITIES OF DALHOUSIE RADIATION SAFETY COMMITTEE:**

a. 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 as low as reasonably achievable (ALARA).

b. Radiation exposures of pregnant Nuclear Energy workers 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 Nuclear Safety and Control Act.
DECLARATION OF PREGNANCY FORM

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.

Worker Name (please print) ______________________ Telephone Number ______________________

Estimated Due Date ________________________________

Signature of Worker ________________________________ Date ___________

Signature of Supervisor ______________________________ Date ___________

Signature of Radiation Safety Officer __________________ Date ___________
DOSE CALCULATION FORM

Worker Name ____________________________

Estimated External Dose ____________
(prior to pregnancy declaration)

External Dose During Remainder of Pregnancy ________________

Internal Dose for Remainder of Pregnancy

From radionuclides in embryo/fetus ____________

From radionuclides in mother ____________

Subtotal ____________

Total Dose During Gestation ____________

Signature of Radiation Safety Officer __________________________________________ Date
INTRODUCTION:

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.

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 Canadian Nuclear Safety Commission and Dalhousie University Radiation Protection Program;

c) other purposes as may be required

Dalhousie University requires that all applicable areas conduct a functional program for the generation and administration of 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. Personal radiation exposure records (including fetal exposure)

2. Personnel bioassay records

3. Receipt of radioactive material records

4. Inventory Records (accounting for stock, in use, disposal)

5. Daily direct monitoring records
6. Weekly wipe test records

7. Leak test records done on sealed sources

8. Incident reports

The above records shall be maintained in a format approved by the Radiation Safety Committee and filed in yellow binders provided by your Radiation Safety Officer. These records must be up to date and available for inspection by radiation safety personnel and officers of the Canadian Nuclear Safety Commission at any time. Personal exposure records are normally kept for fifty years, other records for a minimum of six years.

RECORDS TO BE MAINTAINED IN THE RADIATION SAFETY OFFICE:

1. File of all occupationally exposed workers at Dalhousie University

2. Personal radiation exposure records of all occupationally exposed workers

3. Copies of all active Radioisotope Licences and Radioisotope User permits

4. Listing of all rooms where radioactive materials are used or stored

5. Listing of all radiation survey meters and dose rate meters with their required calibration dates

6. Verification of instrument calibration form

7. Listing of all sealed sources with their required frequency for leak testing

8. Leak test records on all sealed sources

9. Annual inventory records from each licenced area

10. Minutes from Radiation Safety Committee meetings

11. Incident reports

12. Declaration of Pregnancy forms

13. Staff training records

The above records shall be kept up to date and available for inspection by officers of the University and the Canadian Nuclear Safety Commission at any time.
Radioisotope Purchasing Procedure
Dalhousie University

Introduction

Following two incidents in which radioactive materials were fraudulently obtained and informal licensee reports of weaknesses in the control of the purchase and receipt of radioactive materials, staff of the Materials Regulation Division (MRD) of the Canadian Nuclear Safety Commission convened a small workshop with an invited group of knowledgeable and experienced licensees.

Although there are regulatory principles and licence conditions governing this issue, there is no common standard. Consequently, each licensee has developed their own approach. Some have developed and implemented comprehensive processes while others have kept the process very simple. This leads to institutional procedures which are highly variable in their design and operation and, to some degree, in their effectiveness.

To better control the purchase, transfer and receipt of radioactive material, MRD staff determined that one solution might be more stringent regulatory requirements. On June 2, 1997 the Atomic Energy Control Board issued Notice 97-05- Proposed New Radioisotope Licence Conditions to Improve Control of the Ordering and Receiving of Radioactive Material. A copy of these conditions is appended to this procedure.

Purchase Procedure:

1. Purchase requisitions for nuclear substance purchases will be issued by the Radiation Safety Office.

2. All orders for nuclear substances will be placed by the purchasing department.

3. Requests for nuclear substances must be faxed to the Radiation Safety Office. To ensure same day ordering the fax must be received no later than 3:00 pm. It will be necessary to provide complete information including product number, nuclear substance ordered and activity required. Orders for a nuclear substance not listed on an individual permit will not be processed.

4. Completed radioisotope purchase requisitions will be forwarded to Purchasing for processing.
## Management of Radioactive Waste

<table>
<thead>
<tr>
<th>Title:</th>
<th>Management of Radioactive Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number:</td>
<td>RSP - 10</td>
</tr>
</tbody>
</table>

**Revision Date:** 1991, revised September 8, 2006

### Introduction:

Dalhousie University uses nuclear substances under conditions set down by a licence issued by the Canadian Nuclear Safety Commission. Waste disposal is among the many facets of nuclear substance use governed by this licence. Failure to observe the disposal procedures set out below risks harming people or the environment, licence cancellation and even prosecution.

### Categories of Radioactive Waste:

1. **Dry Waste**
   
   Includes dry solid materials, dehydrated biological materials, and *contaminated* papers, glassware, gloves or apparel.

2. **Liquid Waste**
   
   Includes liquid nuclear substances, solutions, contaminated rinses, and liquid scintillation cocktail. Liquid wastes are further categorized as *aqueous* and *non-aqueous*.

   - Aqueous wastes are those considered readily soluble in water.
   - Non-aqueous wastes are those liquids which are not readily soluble in water. These liquids include organic based liquid scintillation fluids.

3. **Biological Waste**
   
   Includes animal carcasses, bedding, solid excreta, tissue, organs, blood, etc..

4. **Sharps**
   
   Includes contaminated broken glass, needles, razor blades, scalpels, etc..

### Disposal and Packaging Procedures:
Dry (solid) Waste

Solid waste containing nuclear substances shall be packaged in the radioactive waste storage boxes available through Tupper stores. These boxes are provided with a two part transfer form which must be completed. Copy 1 remains as the laboratory record of disposal. Copy 2 accompanies the box to storage. Boxes must be lined with an orange garbage bag. Arrangements must be made with the Radiation Safety Officer to transport the waste to the appropriate decay room in either Tupper or the Life Sciences Centre. Transfer form accompanying the box must contain the following information:

i) lab of origin
ii) permit #
iii) date of transfer
iv) nuclear substance(s) contained
v) approximate activity
vi) name of individual who packaged box

Every effort should be made to segregate wastes by nuclear substance, though provisions may be made to mix short lived waste (T > 90 days). Tritium (3H) and Carbon-14 (14C) must be packaged separately. Boxes found to be packaged incorrectly will be returned to the lab of origin for re-packaging.

* Labs with sufficient storage space may opt to store waste for decay in their laboratory. Prior approval must be granted by the RSO and the P.I. must demonstrate that prior to any decayed waste being released a survey is completed to ensure decay to background. All radiation trefoils must be removed prior to release.

Arrangements may also be made to transfer empty Apigs® to the storage rooms.

Liquid Waste

I. Aqueous Liquid Waste

Aqueous liquid waste containing nuclear substances must be decanted to the color-coded 1 gallon bottles provided by the Radiation Safety Office if the amount of radioactivity per litre is in excess of the release limits outlined in Table I. Bottles will be color coded as such:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Time Limit</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short lived nuclear substances</td>
<td>T &gt; 30 days</td>
<td>MAGENTA</td>
</tr>
<tr>
<td>Medium lived nuclear substances</td>
<td>T &gt; 90 days</td>
<td>GREEN</td>
</tr>
<tr>
<td>Long lived nuclear substances</td>
<td>T &gt; 90 days</td>
<td>YELLOW</td>
</tr>
</tbody>
</table>

When full, arrangements must be made with the Radiation Safety Officer to transport the aqueous liquid waste to the appropriate decay room. The outside of the bottle must be clean and free of wet or dried liquids. All information must be included on the bottle tag provided.

Table I
## Dalhousie University Release Limits For Radioactive Materials In Aqueous Liquids
*(lower activities are classified as non-radioactive by the CNSC)*

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon 14</td>
<td>37kBq (1 μCi)/litre of wash</td>
</tr>
<tr>
<td>Chromium 51</td>
<td>37 kBq (1 μCi)/litre of wash</td>
</tr>
<tr>
<td>Tritium</td>
<td>370 kBq (10 μCi)/litre of wash</td>
</tr>
<tr>
<td>Iodine 125</td>
<td>0.37 kBq (0.01 μCi)/litre of wash</td>
</tr>
<tr>
<td>Phosphorus 32</td>
<td>3.7 kBq (0.1 μCi)/litre of wash</td>
</tr>
<tr>
<td>Phosphorus 33</td>
<td>11.1 kBq (0.27 μCi)/litre of wash</td>
</tr>
<tr>
<td>Sulphur 35</td>
<td>3.7 kBq (0.1 μCi)/litre of wash</td>
</tr>
</tbody>
</table>

Any aqueous liquid waste below the criteria set out in the above table may be disposed of to the regular drain, followed by several litres of running water.

## II Non-aqueous Liquid Waste

Liquid scintillation cocktails need not be drained from their counting vials, but rather placed intact in a plastic bag lined cardboard box. The box must be appropriately labeled as to contents including the following information:

- a) lab of origin
- b) nuclear substance
- c) solvent
- d) estimated activity
- e) name of person packaging waste

Arrangements should be made with either the Radiation Safety Office or the Environmental Health and Safety Office for collection. Boxes found to contain materials other than counting vials and their contents will be returned to the lab of origin for repackaging.

## Biological Waste

Arrangements for disposal of radioactive contaminated biological waste should be made through the Radiation Safety Office and the Animal Care Facility. As all biological waste must be shipped for incineration, provisions should be made for refrigerator or freezer storage until arrangements can be made for shipment. Prior to shipment it must be demonstrated that the activity present meets regulatory requirements.

## Sharps

Sharps as defined earlier must be packaged in an approved sharps container for collection and subsequent disposal.

## RESPONSIBILITIES:

### Principal Investigators
In accordance with this procedure and permit conditions the principal investigators are responsible for the collection of all radioactive waste arising from activities under their direction:

a) Determining the waste activity and for separating waste by category

b) Assuring that the radioactive contents do not exceed the indicated quantity.

c) Ensuring that all packaging and disposal procedures are accurately followed. Waste found inappropriately packaged will be the responsibility of the lab of origin to re-package.

d) Maintaining accurate records of disposal routes for all nuclear substances purchased against their Nuclear Substance User Permit.

Radiation Safety Officer

The Radiation Safety Officer is responsible for:

a) Developing policy and procedures for the safe storage, collection, and processing of radioactive waste.

b) Managing waste disposal program in accordance with the terms and conditions of the university’s Nuclear Substances and Radiation Devices Licence as issued by the CNSC.
NUCLEAR SUBSTANCES

The radiation dose received by any person from external or internal exposure to 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 represents a risk, very small compared to the other risks voluntarily encountered in 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 Dalhousie University Nuclear Substances and Radiation Devices Licence are to be advised of the following policy. This policy has been developed to reduce the risk and/or severity of unnecessary radiation exposure to staff. Animal users are to notify the Animal Care supervisor one week prior to beginning the use of nuclear substances.

Housing Within the Animal Care Centre:

1. Animals to be used in any study involving in vivo use of nuclear substances are to be housed in a separate room specifically designated for that purpose by the Animal care supervisor in consult with the Radiation Safety Officer. This room will contain a decontamination kit in the event of a radioactive spill.

2. 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 and the RSO’s name and phone number.

3. In addition an appropriate warning sign must be posted on the cage in which the animal is housed.

4. 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 labeled 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. Suitable plastic bags and appropriately marked boxes are available from Central Stores. 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.

5. Animal handlers are to double glove at all times when working in rooms with radiation hazard sign posting. 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 by the permit. Gloves and shoe covers must be removed and disposed of before exiting the room.

6. Upon completion of the project, or as required, the properly packaged radioactive waste must be disposed of as per university guidelines.

7. Prior to sending out any used cages, racks or boxes for cleaning, rooms and cages must be monitored and wipe tested for any residual radioactivity. The required wipe test procedure/form will be provided by the Animal care supervisor. Results will be recorded on the form provided. These results will then be forwarded to the RSO for interpretation. Once results have been checked and an independent audit done by the RSO, if necessary, the room will be opened for use. Cages etc, will be forwarded to cage wash for sanitation.

Transportation of Animals Off Site:

1. If the animal is to be transported to an other area within the Tupper building, the cage shall be moved by cart via the service elevators to the designated area.

2. If the animal is to be transported off site, along with Animal Care personnel the RSO must be notified. 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.

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

4. If animals are too transferred to an off site location not covered by the Dalhousie University licence 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 licenced to use both the radioisotope in question as well as in vivo use in animals.

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

____________________    ______________________
Pauline Jones               Dr. Sylvia Craig
Radiation Safety Officer    University Veterinarian
Dalhousie University        Dalhousie University
Radiation Safety Policy and Procedure

Title: Radiation Safety Training Policy  
Number: RSP - 014  
Date: December 7, 2005

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 Office 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.

Radiation Safety Training sessions will be scheduled three times annually, typically in May, August and December.

Training Procedure:

New workers who will be designated as a Worker Approved to Use/Handle Nuclear Substances shall be registered with the Radiation Safety Office within seven days of joining the research group.

1. The Principal Investigator or his/her designate shall ensure that all new workers read the laboratory copy of the Radiation Safety Training Manual and sign that they have done so prior to any work with nuclear substances.

2. The Principal Investigator shall ensure that all new workers register for the first available Radiation Safety Training course available after the worker has joined the research group. Schedules of available training sessions, as well as registration forms are posted annually to the EH&S web site at http://www.dal.ca/safety.

3. New workers may be exempted from participating in the training session if they are able to demonstrate by means of a training certificate that they have attended a training session held at another Canadian institution with the past twenty-four (24) months.

4. Worker re-training is required every twenty-four (24) months. An on-line Power-Point training session will be posted to the EH&S web site in June of each calendar year. Workers who are required to re-train must complete the on-line session and complete a short quiz with a minimum 80% pass rate. Workers who do not complete the re-successfully pass the quiz will be removed from the authorized worker list.
Title: Laboratory Status  
Number: RSP-002  
Date: December 7, 2005  

The status of all Nuclear Substance User Permits will be reviewed annually. If no work with nuclear substances has been performed and no inventory is on hand the Principal Investigator will be given the option of:

a) Decommissioning the laboratory by following the procedure as set out in Dalhousie University’s *Policy for the Termination of Nuclear Substance Use - Renovations, Remodels, Moves, and Terminations.*

b) Placing their permit as *inactive.* To do so would require that the most recent wipe test result be submitted to the Radiation Safety Office and all signage be removed.

If no work with nuclear substances has been performed and inventory is on hand the P.I. will be required to change their permit to a *storage only* status. To do so would require that the most recent wipe test result be submitted to the Radiation Safety Office.
Title: Transfer/shipment of nuclear substances and/or radiation devices
Number: RSP - 004
Date: December 7, 2005

Transfers of nuclear substances and/or radiation devices are permitted. Transfers from one permit holder to another within the same department are permitted by making the appropriate notations on respective inventory control sheets. A transfer form is not required. Transfers from one permit holder to another in different departments or different physical locations on campus are permitted provided the material falls under the category excepted radioactive material, limited activity. In this case a transfer form is required along with the appropriate notations on respective inventory control sheets.

Transfers of nuclear substances and/or radiation devices that do not fall into the above category but will remain on campus must be coordinated by the Radiation Safety Officer. The RSO will have the required TDG training.

Transfers of nuclear substances and/or radiation devices to another licensee must be coordinated by the RSO. The RSO will determine through contact with the RSO at the receiving institution whether the shipment can be transported to and received by the licensee.

Prior to any transfer of nuclear substances and/or radiation devices to Dalhousie University from another licensee approval to receive must be granted by the RSO.
Each research group will be required to conduct a nuclear substance laboratory self-audit (attached) on a twice yearly basis, in May and November. These audits will be reviewed by the RSO and appropriate corrective action taken within one week of receipt of the audit.

Twice yearly to correspond with research group self-audits, the RSO will verify the results of a minimum of 50% of the audits. Research groups to be audited will be selected randomly.
Title: Licenced Activity Commissioning – CNSC Reporting Requirements
Number: RSP - 017
Date: March 1, 2008
Approved by: Radiation Safety Committee

The Nuclear Safety & Control Act and accompanying Regulations dictate several conditions where a licensee must notify the CNSC of changes. The applicable legislation includes:

- Nuclear Safety & Control Act
- General Nuclear Safety & Control Regulations
- Radiation Protection Regulations

It is the responsibility of the Radiation Safety Officer, or in his/her absence the Director of Environmental Health & Safety, to notify the CNSC within the required time frame. CNSC may be contacted by calling 1-800-668-5284.

<table>
<thead>
<tr>
<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>The commissioning of a licenced activity for a period of &gt; 90 days</td>
<td>Within 7 days of the commencement of the activity</td>
</tr>
</tbody>
</table>
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<thead>
<tr>
<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>The decommissioning of a licenced activity</td>
<td>Within 7 days of the decommissioning</td>
</tr>
</tbody>
</table>
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<thead>
<tr>
<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Thyroid screening of personnel detects activity &gt; 10 kBq</td>
<td>An immediate preliminary report must be made followed by thyroid bioassay within 24 hours of detection.</td>
</tr>
</tbody>
</table>
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<tr>
<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>The licensee is required to submit an ACR annually</td>
<td>The report must be received by CNSC by April 30th of each year.</td>
</tr>
</tbody>
</table>
Title: Exceeding of Licensee’s Action Levels – CNSC Reporting Requirements

Number: RSP - 021

Date: March 1, 2008

Approved by: Radiation Safety Committee

The Nuclear Safety & Control Act and accompanying Regulations dictate several conditions where a licensee must notify the CNSC of changes or occurrences. The applicable legislation includes:

- Nuclear Safety & Control Act
- General Nuclear Safety & Control Regulations
- Radiation Protection Regulations

It is the responsibility of the Radiation Safety Officer, or in his/her absence the Director of Environmental Health & Safety, to notify the CNSC within the required time frame. CNSC may be contacted by calling 1-800-668-5284.

### Occurrence Reporting Time Frame

| Exceeding of licensees action levels | Immediate notification |

### Personal Dose Limits

<table>
<thead>
<tr>
<th>Item</th>
<th>Person</th>
<th>Period</th>
<th>Effective Dose (mSv)</th>
<th>Action Level (mSv/quarter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a person who is not a NEW</td>
<td>1 calendar year</td>
<td>1 mSv</td>
<td>0.3 mSv</td>
</tr>
<tr>
<td>2</td>
<td>a person who is not a NEW lens of an eye</td>
<td>1 calendar year</td>
<td>15 mSv</td>
<td>5 mSv</td>
</tr>
<tr>
<td>3</td>
<td>a person who is not a NEW skin</td>
<td>1 calendar year</td>
<td>50 mSv</td>
<td>16 mSv</td>
</tr>
<tr>
<td>4</td>
<td>a person who is not a NEW hands &amp; feet</td>
<td>1 calendar year</td>
<td>50 mSv</td>
<td>16 mSv</td>
</tr>
</tbody>
</table>

### Contamination Levels

<table>
<thead>
<tr>
<th>Class</th>
<th>Control Area Limit</th>
<th>Public Area/Decommissioning Limit</th>
<th>Dalhousie 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>
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<tr>
<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Exceeding of personal dose limits</td>
<td>Immediate notification followed by a written investigation report within 21 days.</td>
</tr>
</tbody>
</table>
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<tr>
<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes to representatives of applicants and</td>
<td>The change must be reported to the CNSC</td>
</tr>
<tr>
<td>licensees</td>
<td>within 15 days</td>
</tr>
</tbody>
</table>
Title: Retention and Disposal of Records – CNSC Reporting Requirements
Number: RSP - 024
Date: March 1, 2008
Approved by: Radiation Safety Committee

The Nuclear Safety & Control Act and accompanying Regulations dictate several conditions where a licensee must notify the CNSC of changes or occurrences. The applicable legislation includes:

- Nuclear Safety & Control Act
- General Nuclear Safety & Control Regulations
- Radiation Protection Regulations

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<thead>
<tr>
<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention and disposal of records</td>
<td>CNSC must be notified a minimum of 90 days prior to the proposed disposal date.</td>
</tr>
</tbody>
</table>
The Nuclear Safety & Control Act and accompanying Regulations dictate several conditions where a licensee must notify the CNSC of changes or occurrences. The applicable legislation includes:

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<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss or theft of nuclear substances, prescribed equipment or prescribed information</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
</tr>
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- Nuclear Safety & Control Act
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- Radiation Protection Regulations

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<th>Occurrence</th>
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<tr>
<td>Contravention of the Act in relation to an activity</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
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<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Occurrence likely to result in exposure exceeding applicable dose limits</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
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<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Unauthorized release of radioactivity to the environment</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
</tr>
</tbody>
</table>
Title: Situation or event requiring implementation of a contingency plan – CNSC Reporting Requirements

Number: RSP – 030

Date: March 1, 2008

Approved by: Radiation Safety Committee

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<th>Occurrence</th>
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<tbody>
<tr>
<td>Situation or event requiring implementation of a contingency plan</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
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<th>Occurrence</th>
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</tr>
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<tbody>
<tr>
<td>Breach of security or act of sabotage – actual or attempted</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
</tr>
</tbody>
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<tr>
<th>Occurrence</th>
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<tbody>
<tr>
<td>Actual, threatened or planned work disruption</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
</tr>
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<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death of a person at a nuclear facility</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
</tr>
</tbody>
</table>
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<th>Occurrence</th>
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</thead>
<tbody>
<tr>
<td>Bankruptcy</td>
<td>An immediate preliminary report must be made to CNSC followed by a full written report within 21 days of occurrence</td>
</tr>
</tbody>
</table>
Title: Deficiencies in records – CNSC Reporting Requirements

Number: RSP – 035

Date: March 1, 2008

Approved by: Radiation Safety Committee

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General Nuclear Safety & Control Regulations
Radiation Protection Regulations

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<tr>
<th>Occurrence</th>
<th>Reporting Time Frame</th>
</tr>
</thead>
<tbody>
<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>
</tbody>
</table>
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<tr>
<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Positive leak test – activity measured in excess of 200 Bq</td>
<td>A report must be submitted to CNSC immediately after becoming aware of failed test – source must be immediately removed from service and any contamination remediated</td>
</tr>
</tbody>
</table>
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<tr>
<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Loss or damage to an exposure device or sealed source</td>
<td>A report must be submitted to CNSC immediately with a full written report within 21 days</td>
</tr>
</tbody>
</table>
The Nuclear Safety & Control Act and accompanying Regulations dictate several conditions where a licensee must notify the CNSC of changes or occurrences. The applicable legislation includes:

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- Radiation Protection Regulations
- Packaging and Transport of Nuclear Substances Regulations

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<tr>
<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<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>
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</table>
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<th>Occurrence</th>
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</thead>
<tbody>
<tr>
<td>Transportation – damaged shipment</td>
<td>A report must be submitted to the CNSC and the Consignor within 21 days</td>
</tr>
</tbody>
</table>
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<th>Occurrence</th>
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<tbody>
<tr>
<td>Transportation – tampered with package</td>
<td>An immediate preliminary report must be submitted followed by a full written report within 21 days</td>
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<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Transportation – undeliverable consignments</td>
<td>An immediate report must be submitted</td>
</tr>
</tbody>
</table>
Title: Use of more than 2 GBQ for tracer studies – CNSC Reporting Requirements

Number: RSP – 042

Date: March 1, 2008

Approved by: Radiation Safety Committee

The Nuclear Safety & Control Act and accompanying Regulations dictate several conditions where a licensee must notify the CNSC of changes or occurrences. The applicable legislation includes:

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Radiation Protection Regulations

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<tr>
<th>Occurrence</th>
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</tr>
</thead>
<tbody>
<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>
</tbody>
</table>

Section 8 – Sealed Sources
INTRODUCTION

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 Ni-63 used in gas chromatography.

The inventory and leak testing of sealed sources is regulated under the conditions of Dalhousie University’s consolidated radioisotope license issued by the Canadian Nuclear Safety Commission. 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
- SOURCE REDUCTION
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 RSO identification
- isotope
- activity
- assay date

LEAK TESTING OF SEALED SOURCES

The Canadian Nuclear Safety Commission requires in Section 18 of the Nuclear Substances and Radiation Devices Regulations

1. Subject to subsection (2), every licensee who possesses, uses or produces either a sealed source containing 50 MBq or more of a nuclear substance or a nuclear substance as shielding shall, at the following times, conduct leak tests on the sealed source or shielding using instruments and procedures that enable the licensee to detect a leakage of 200 Bq or less of the nuclear substance:

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

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

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

   d) in all other cases,

      i) where the sealed source or shielding is located in a radiation device, every 12 months, and

      ii) where the sealed source or shielding is not located in a radiation device, every six months.
Section 9 - GAMMACELL IRRADIATORS

Gamma cell irradiators are designed to provide a large uniform gamma field for the irradiation of samples.

For radiation protection purposes, external dose is the primary concern to the operator when using the unit.

DOSE RATES ASSOCIATED WITH GAMMACELL IRRADIATORS

Gamma cell irradiators provide a large gamma dose to samples. The most commonly used radioisotopes in these irradiators are Co-60 or Cs-137. The Gamma cell irradiator at Dalhousie University contains a 40 TBq Co-60 source. The sources are sealed sources, normally comprised of stainless steel encapsulation.

Sources are commonly provided as a line source, similar in shape to a pencil. Within a sample chamber, this shape enables the exposure to be provided as a uniform dose over a larger distance. A point source projects the dose differently, as radiation coming from a single small point. When the distance from a line source is increased (about three times the length of the source) the line source acts as a point source. The exposure to the operator would be considered a point source due to the distance from the source itself.

The containment vessel of the system is normally heavily shielded, typically with lead. The dose rates on the outside of most systems, approximately one foot from the source, are normally < 0.025 mSv/hr when the source is in the expose position.. This is the highest potential for an exposure to the operator. When the source is in the safe position, the source is more heavily shielded. When the system is in the expose position, the level of exposure to the operator, one foot from the source calculated for a working year would be:

\[ 0.025 \text{ mSv/hr} \times 40 \text{ hour/week} \times 50 \text{ weeks/year} = 50 \text{ mSv} \]
Routinely, the operator is only at this location for a few minutes at any one time. The systems are designed with interlocks and other safety features to minimize any potential exposure to operators. These are designed to move the source into the safe position if the chamber is opened or other situations arise. Administrative controls are established to make sure the area is clear and ensure that the operators have the appropriate training. This control normally includes control of the key to the system. Workers using the system must be monitored for whole body gamma exposures.

**SYSTEM OPERATION**

Verify that the source is in the “OFF” position before attempting to open the chamber door. After placing the sample into the chamber check the interlocks before placing the source in the active position.

After using the irradiator, document use in the log book.

The operator should stay outside the room when the unit has the source in the active position. If the sample will be left in the irradiator for an extended period of time while the operator is not attending the system, the area must be locked.

In the event of a problem with the system, the RSO should be contacted.

**EMERGENCY PROCEDURES**

In the event of malfunction during loading or unloading of the irradiator, the unit is to be taken out of service immediately. Evidence of malfunction includes binding or moving parts, the presence of metal shavings or chips etc..

1. Log and describe any abnormal occurrences in the use log book
2. Should the “Release Source” fail, leave/secure the room immediately and contact the RSO
3. If at any time it is possible to open the cavity door without pressing the door release button, the interlock assembly is malfunctioning. Do not use the unit! Leave/secure the room and contact the RSO.
4. If at any time it is impossible to raise the source with the door closed or to open the door with the source in the “OFF” position, either the interlock switches or interlock solenoids are malfunctioning. Do not use the unit! Leave/secure the room and contact the RSO.

**RESPONSIBILITIES**

1. The principal investigator must
   ( a ) maintain the irradiator in a clean and mechanically functional condition
   ( b ) ensure that designated users receive training as required
   ( c ) ensure that designated users wear whole body dosimeters when operating the unit
   ( d ) list and certify designated users
   ( e ) ensure physical security of the key to the unit and prevent unauthorized use of the
irradiator

(f) notify the RSO immediately of any malfunctions or problems with the irradiator

(g) arrange for repairs or maintenance of the unit by appropriate persons

2. **Designated users must**

(a) operate the unit in accordance with the established procedures at all times

(b) wear a whole body dosimeter when operating the irradiator

(c) notify the principal investigator and the RSO of any malfunctions or problems with the irradiator

(d) ensure that the key is returned to secure storage following irradiation

3. **Radiation Safety Personnel must**

(a) maintain the license/permit issued to the facility by CNSC/Dalhousie for operation of the irradiator

(b) conduct leak tests annually

(c) provide appropriate training

**Change of Principal Investigator**

If transfer of responsibility for the irradiator is contemplated, the new applicant must apply for authorization.

**Individuals who may wish to use the Gamma cell Irradiator must be registered with the Radiation Safety Office and receive specific training in the safe use and operation of the unit. The training is provided by the laboratory manager in charge of the Gamma cell Irradiator.**
NUCLEAR SUBSTANCE USER PERMIT

Issued by the Radiation Safety Committee
Dalhousie University, Halifax

Authorized by the Canadian Nuclear Safety Commission
CNSC Nuclear Substance Licence # 07154-2-12.2

1. Nuclear Substance User Permit #: 150900-03
   Date Of Issue: February 1, 2007
   Expiry Date: January 31, 2009

2. Principal Investigator: Melissa Michaud

3. Department: Radiation Safety

4. Location(s) Approved By This Permit
   Tupper: Waste Storage Room -xxxx
   LSC: Waste Storage Area -yyyy

5. Nuclear Substance: Any radioisotope Atomic Numbers 1-89, to be held for ten half lives

6. Personal Dosimeters Are _____; Are _____ Not Required
   Extremity Dosimeters Required __________

7. Approved Use:
   Waste storage for decay and disposal

8. Method Of Disposal:
   Refer to Dalhousie University=s Management of Radioactive Waste@ policy

9. Special Conditions:
   Access to area controlled by Radiation Safety Officer

____________________________________________
Radiation Safety Officer
Dalhousie University
Nuclear Substance User Permit
Schedule of Conditions

The Schedule of Conditions is to be kept with and forms part of each Nuclear Substance User Permit issued by the Dalhousie University Radiation Safety Committee.

1. Nuclear Substance User Permits are issued subject to the provisions of the Dalhousie University Radiation Safety Program.

2. A copy of the Nuclear Substance User Permit and all attachments or amendments thereto must be displayed in each location approved by this permit.

3. A copy of either AUlles For Working With Radioisotopes In A Basic Laboratory or ARules For Working With Radioisotopes In An Intermediate Laboratory® (depending on laboratory classification) must be posted. The name and telephone number of the person to contact in an emergency must be clearly stated at the top of the poster. All workers must comply with the rules stated.

4. Principal investigators (permit holders) are responsible for registering all persons under their supervision with the Radiation Safety Office 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.

13. Principal investigators are responsible for ensuring that all personnel working under their supervision wear all required personal protective equipment (PPE) while handling nuclear substances.

6. Where nuclear substances are used for teaching purposes a copy of the ATeaching Laboratory Enrollment form must be filed with the Radiation Safety Office to record the names of students who will handle radioisotopes in each academic term.

7. Where nuclear substances will be used in animals which will undergo surgical procedure or will be housed in the Animal Care Centre of the Tupper Building, notification must be given to the Director of Animal care at least one week in advance.

8. Nuclear Substance User Permit Holders who will be taking sabbatical or other leave must designate another qualified person to assume responsibilities for the use of nuclear substances under the conditions outlined in the permit. The Radiation Safety Office must be notified in advance of this alternate.

9. Appropriate inventory records using the standard university inventory control forms must be maintained for inspection by the Radiation Safety Officer. These records must be maintained in accordance with Dalhousie University Record Keeping Requirements®.

10. Purchasing of nuclear substances must be in accordance with Dalhousie University’s ANuclear Substance Purchasing Procedure.

11. Records of internal transfer of radioactive material must be maintained, both by supplier and recipient in accordance with Dalhousie University Record Keeping Requirements policy.

12. Radiation warning symbols must be prominently displayed wherever radioactive materials are used.
or stored.

13. **Nuclear substances must be stored in a secure container marked with a radiation warning symbol. This sign should also contain twenty four hour contact information and equipped with a lock approved by the Radiation Safety Office.**

14. **Work areas shall be monitored for contamination and radiation levels on a regular basis (at least weekly). Records of such monitoring shall be maintained and available for inspection by radiation safety personnel. Records shall be maintained in accordance with Dalhousie University Record Keeping Requirements.**

o) **Laboratory must be locked at all times when unoccupied. No unauthorized person is permitted access to the laboratory without the supervision of an authorized nuclear substance worker.**

p) **Any loss or theft of a nuclear substance must be reported to both Security and the Radiation Safety Office within 24 hours of discovery of the loss. An inventory audit of all radioactive materials must be conducted and the report submitted to the Radiation Safety Office within 48 hours.**

17. **Do not eat, drink, and store food or smoke in areas where nuclear substances are used or stored.**

18. **Nuclear Substance User Permits do not convey approval for the administration of radioisotopes to humans.**

June 2004
Dalhousie University  
Special Conditions  

Nuclear Substance User Permit #:______________________________  

(   ) a. Live animals containing nuclear substances must be housed in an appropriately marked cage. Any waste products must be treated as radioactive waste unless it can be shown to be below prescribed levels.  

(   ) b. Survey instrumentation capable of the efficient detection of the radioiodine used must be available and turned on throughout any manipulation in which radioiodine is used.  

(   ) c. Areas where radioiodine is used MUST be monitored daily for possible contamination and records kept. Any iodine held in storage should be at a pH > 8.  

(   ) d. The Radiation Safety Office MUST be notified 24 hours in advance of a radioiodination.  

(   ) e. Radioiodinations MUST be carried out in a properly functioning fume hood. Thyroid monitoring shall be carried out on a regular basis, by arrangement with the Radiation Safety Office.  

(   ) f. Monitoring of all work surfaces MUST be carried out at the end of each work day on which P-32 was used. Records of such surveys MUST be maintained.  

(   ) g. Staff working with P-32 MUST wear a finger TLD monitor as well as the whole body dosimeter.  

(   ) h. Areas where C-14 is used must be wipe tested weekly for possible contamination and records kept.  

(   ) i. Areas where H-3 is used must be wipe tested weekly for possible contamination and records kept.  

(   ) j. Areas where S-35 is used must be wipe tested on a weekly basis for possible contamination and records kept.  

(   ) k. Areas where P-33 is used must be wipe tested on a weekly basis for possible contamination and records kept.  

(   ) l. Sealed sources must be leak tested and records kept as required in section 18 of the *Nuclear Substances & Radiation Devices* regulations. This leak testing will be coordinated through the Radiation Safety Office at the required frequency.
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.

24 hour emergency contact (name and phone number)

Safety Precautions

1. Keep laboratory locked when unattended.
2. Supervise nuclear substances at all times when in use.
3. Ensure that all staff are aware of their responsibilities and obligations as radiation workers.
5. Comply with Dalhousie University permit conditions.
6. Do not consume or store food and/or drink in this laboratory.
7. Wear required personal protective equipment while working with nuclear substances.
8. Wear whole body and ring TLD monitors if required by permit.
9. Clearly identify work areas used for handling nuclear substances.
10. Work in a fume hood when handling dry powders or volatile substances.
11. Do not pipette by mouth.
12. Cover work surfaces with absorbent liners.
13. Follow proper receipt procedures for packages containing nuclear substances.
14. Maintain an up-to-date inventory for all stock solutions of radioactive material.
15. Monitor laboratory for loose contamination at least weekly. Maintain record of results and decontaminate if necessary.
16. Maintain records of non-use periods.
17. Maintain good personal hygiene (hand washing) and good housekeeping practices.

Storage and Waste Disposal

1. Affix radioactive warning symbols and contact information to storage areas and waste containers.
2. Regularly transfer radioactive waste to designated storage areas.
3. Dispose of radioactive waste as per Dalhousie University “Management of Radioactive Waste” policy.

Accidents and Radioactive Spills

1. Follow Dalhousie University’s “Radioactive Spill Clean-Up Procedure”.

Laboratory Requirements

1. Required personal protective equipment
2. Radioactive Spill Kit
3. Required monitoring equipment

Emergency Numbers
1. Security  9 - 494 - 4109
2. RSO      9 - 494 - 1938 or  9 – 403-3063 (cell phone)
REGULATORY LIMITS AND ACTION LEVELS

CNSC criteria for radioactive contamination

The licensee shall ensure that for nuclear substances listed on the licence application guide table titled "Classification of Radionuclides";

a) non-fixed contamination in all areas, rooms or enclosures where unsealed nuclear substances are used or stored does not exceed:

i) 3 becquerels per square centimetre for all Class A radionuclides;
ii) 30 becquerels per square centimetre for all Class B radionuclides; or
iii) 300 becquerels per square centimetre for all Class C radionuclides; averaged over an area not exceeding 100 square centimetres; and

a) non-fixed contamination in all other areas does not exceed:

i) 0.3 becquerels per square centimetre for all Class A radionuclides;
ii) 3 becquerels per square centimetre for all Class B radionuclides; or
iii) 30 becquerels per square centimetre for all Class C radionuclides; averaged over an area not exceeding 100 square centimetres.

Dalhousie University ALARA Program Requirements

<table>
<thead>
<tr>
<th>Contamination Level</th>
<th>Action Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.3 Bq/cm² for Class A radionuclides</td>
<td>Post result as &quot;no contamination&quot; or Y</td>
</tr>
<tr>
<td>&lt;3 Bq/cm² for Class B radionuclides &lt;30 Bq/cm² for Class C radionuclides</td>
<td>Post result as &quot;no contamination&quot; or Y</td>
</tr>
<tr>
<td>Work surfaces &gt; 3 Bq/cm² for Class B &amp; &gt; 30 Bq/cm² for Class C radionuclides</td>
<td>♦ clean the area immediately ♦ re-monitor and repeat cleaning until all contamination is removed or further cleaning does not decrease contamination levels</td>
</tr>
<tr>
<td>All other surfaces &gt;3 Bq/cm² for Class B &amp; &gt; 30 Bq/cm² for Class C radionuclides</td>
<td>♦ record contamination levels before and after cleanup</td>
</tr>
</tbody>
</table>
Radiation Safety “Rules of Thumb”

1. It requires a beta particle of at least 70 keV to penetrate the protective layer of the skin, 0.07 mm thick.

2. The range of a beta particle in air is about 12 feet per MeV; a 1.7 MeV beta ($^{32}$P) has a range of 20 feet in air.

3. The intensity of bremsstrahlung increases approximately with the energy of the beta particle and about the square of the atomic number of the shielding material.

4. When betas of 1-2 MeV pass through light materials such as water, aluminum, or glass, less than 1% of their energy is dissipated as bremsstrahlung.

5. The bremsstrahlung from 37 MBq (1 mCi) of P-32 aqueous solution in a glass bottle is about 0.001 mR/hr at 1 meter, and about 0.1 mR/hr at 10 cm, and about 10 mR/hr at 1 cm.

6. The activity of any radionuclide is reduced to less than 1% after 7 half-lives and is reduced to less than 0.1% after 10 half-lives.
### Selection of Contamination Monitoring Instruments

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>T</th>
<th>Principal Emission</th>
<th>Energy (keV)</th>
<th>Hand-held Instrument</th>
<th>Non-portable Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3</td>
<td>12.3 y</td>
<td>β</td>
<td>5.7 keV</td>
<td>6</td>
<td>B</td>
</tr>
<tr>
<td>C-14</td>
<td>5730 y</td>
<td>β</td>
<td>49 keV</td>
<td>1,2,3,6</td>
<td>A,B</td>
</tr>
<tr>
<td>P-32</td>
<td>14.3 d</td>
<td>β</td>
<td>690 keV</td>
<td>1,2,3,6</td>
<td>A,B</td>
</tr>
<tr>
<td>P-33</td>
<td>25.4 d</td>
<td>β</td>
<td>85 keV</td>
<td>1,2,3,6</td>
<td>A,B</td>
</tr>
<tr>
<td>Cr-51</td>
<td>27.8 d</td>
<td>γ</td>
<td>320 keV</td>
<td>3,6</td>
<td>B,C,D</td>
</tr>
<tr>
<td>Tc-99m</td>
<td>6 h</td>
<td>γ</td>
<td>141 keV</td>
<td>2,3,4,5,6</td>
<td>A,B,C,D</td>
</tr>
<tr>
<td>I-125</td>
<td>60.1 d</td>
<td>γ</td>
<td>35 keV</td>
<td>2,4,6</td>
<td>B,C,D</td>
</tr>
<tr>
<td>Cs-137</td>
<td>30 y</td>
<td>β</td>
<td>157 keV</td>
<td>1,2,3,5,6</td>
<td>A,B,C,D</td>
</tr>
<tr>
<td>S-35</td>
<td>87.4 d</td>
<td>β</td>
<td>53 keV</td>
<td>1,2,3,6</td>
<td>A,B</td>
</tr>
</tbody>
</table>

#### Hand-held Instrument

- Thin window GM detector
- Ion chamber with β window
- Gas filled proportional counter
- Thin layer NaI detector
- Thin crystal NaI detector
- Zinc sulphide detector

#### Non-portable Instrument

- Gas flow proportional counter
- LS counter
- Well crystal NaI counter
- Semiconductor γ spectrometer

---

Radiation Safety Training Manual 2011
## NUCLEAR SUBSTANCE SHIPMENT RECEIPT

<table>
<thead>
<tr>
<th>Date Rec’d</th>
<th>Nuclear Substance</th>
<th>Vendor</th>
<th>Lot #</th>
<th>Pkg. O.K.</th>
<th>Problem (specify)</th>
<th>Initials</th>
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</thead>
<tbody>
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</table>
NUCLEAR SUBSTANCE INVENTORY RECORDS

Under the CNSC *A N u c l e a r  S u b s t a n c e s  a n d  R a d i a t i o n  D e v i c e s  R e g u l a t i o n s* Section 36 states:

- Every licensee shall keep the following records:
  - a record of the following information in respect of any nuclear substance in the licensee’s possession that is referred to in the license:
    - I. the name, quantity, form and location of the nuclear substance,
    - II. where the nuclear substance is a sealed source, the model and serial number of the source,
    - III. where the nuclear substance is contained in a radiation device, the model and serial number of the device,
    - IV. the quantity of the nuclear substance used, and
    - V. the manner in which the nuclear substance was used;
  - a record of the name of each worker who uses or handles a nuclear substance;
  - a record of any transfer, receipt, disposal, or abandonment of a nuclear substance,
Radioisotope Inventory Record (1 stock/sheet)

<table>
<thead>
<tr>
<th>Permit Holder: ___________________</th>
<th>Permit #: ___________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Rec’d (d/m/y) ___________</td>
<td>Assay Date (d/m/y) ___________</td>
</tr>
<tr>
<td>Isotope: ___________</td>
<td>Product: _______________</td>
</tr>
<tr>
<td>Vial ID # (affix sticker)</td>
<td>Shipment Lot #: _______________</td>
</tr>
<tr>
<td>Package checked for contamination by: ___________</td>
<td>Sign off date (d/m/y) ___________</td>
</tr>
</tbody>
</table>

### USE:

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</tbody>
</table>

Radiation Safety Training Manual 2011
Regulatory Limits for Radioactive Contamination

CNSC license criteria for radioactive contamination:

The licensee shall ensure that for nuclear substances listed in the license application guide table entitled Classification of Radionuclides:

a) non-fixed contamination in all areas, rooms or enclosures where unsealed nuclear substances are used or stored does not exceed

   I. 3 becquerels per square centimetre for Class A radionuclides;
   II. 30 becquerels per square centimetre for all Class B radionuclides; or
   III. 300 becquerels for all Class C radionuclides;

averaged over an area not exceeding 100 square centimetres; and

b) non-fixed contamination in all other areas does not exceed:

   IV. 0.3 becquerels per square centimetre for all Class A radionuclides;
   V. 3 becquerels per square centimetre for all Class B radionuclides; or
   VI. 30 becquerels per square centimetre for all Class C radionuclides;

averaged over an area not exceeding 100 square centimetres

Notwithstanding these limits which are based on possible health risks, licensees shall maintain levels of radioactive contamination as low as reasonably achievable (ALARA) as defined in Dalhousie University ALARA Policy
Regulatory Limits and Action Levels

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 emit beta and gamma radiation  
**Class C** - typically short lived and emit beta and gamma radiation

### Classification of Selected Radionuclides

<table>
<thead>
<tr>
<th>Class</th>
<th>Radionuclide</th>
</tr>
</thead>
</table>
| Class A | Na-22, Na-24, Co-60, Ir-192, Sb-124, Ta-182, Zn-65  
All alpha emitters and their daughter isotopes |
| Class B | As-74, Au-198, Br-82, Co-58, F-18, Fe-59, Ga-67, Gd-153  
Hg-203, I-131\(^{1}\), In-111\(^{1}\), In-114m, Nb-95, Rb-84, Rb-86, Sc-46  
Se-75, Sm-153, Sn-113, Sn-123, Sr-85, Sr-90 |
| Class C | Au-195m, C-14\(^{1}\), Ca-45, Cd-109, Ce-144, Cl-36, Co-57, Cr-51\(^{1}\)  
H-3\(^{1}\), I-123, I-125\(^{1}\), Ni-63, P-32\(^{1}\), P-33\(^{1}\), Re-186, Re-188, Ru-103  
S-35\(^{1}\), Sr-89, Tc-99, Tc-99m, Tl-201, Y-90, Yb-169 |

* These radionuclides are commonly used at Dalhousie University.

At Dalhousie University Class B and Class C radionuclides are typically used. In keeping with an 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 Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3 Bq/cm(^{2})</td>
<td>0.3 Bq/cm(^{2})</td>
<td>0.3 Bq/cm(^{2})</td>
</tr>
<tr>
<td>B</td>
<td>30 Bq/cm(^{2})</td>
<td>3 Bq/cm(^{2})</td>
<td>3 Bq/cm(^{2})</td>
</tr>
<tr>
<td>C</td>
<td>300 Bq/cm(^{2})</td>
<td>30 Bq/cm(^{2})</td>
<td>30 Bq/cm(^{2})</td>
</tr>
</tbody>
</table>

### Dalhousie University Action Levels

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Counting Method</th>
<th>Nominal Efficiency</th>
<th>Net Count Rate for 3 Bq/cm(^{2})</th>
<th>Net Count Rate for 30 Bq/cm(^{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-14</td>
<td>LSC</td>
<td>50%</td>
<td>900 cpm</td>
<td>9000 cpm</td>
</tr>
<tr>
<td>H-3</td>
<td>LSC</td>
<td>30%</td>
<td>540 cpm</td>
<td>5400 cpm</td>
</tr>
<tr>
<td>P-32</td>
<td>LSC</td>
<td>50%</td>
<td>900 cpm</td>
<td>9000 cpm</td>
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<tr>
<td></td>
<td>Direct (pancake)</td>
<td>20%</td>
<td>506 cpm</td>
<td>5060 cpm</td>
</tr>
<tr>
<td>P-33</td>
<td>LSC</td>
<td>50%</td>
<td>900 cpm</td>
<td>9000 cpm</td>
</tr>
<tr>
<td>S-35</td>
<td>LSC</td>
<td>50%</td>
<td>900 cpm</td>
<td>9000 cpm</td>
</tr>
</tbody>
</table>

For LSC, the nominal efficiency is assumed to be 50% of the counter efficiency for an unquenched sample. This is generally conservative and takes into consideration that wipes collected from lab surfaces may have higher quench than normal laboratory samples.

Wipes are all assumed to be 100 cm\(^{2}\) with a collection efficiency of 10% on a wet wipe and 1% on a dry wipe.
<table>
<thead>
<tr>
<th>Week Of</th>
<th>Nuclear Substance Used</th>
<th>Nuclear Substance Not Used</th>
<th>Week Of</th>
<th>Nuclear Substance Used</th>
<th>Nuclear Substance Not Used</th>
</tr>
</thead>
<tbody>
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</table>
WIPE TEST PROCEDURE

1. On a plan of the laboratory, mark locations that are to be tested.

2. Using filter paper or cotton swab moistened with a suitable solvent (water or alcohol), wipe a representative area (50 - 100 sq. cm.) in each of the designated locations. Use one wipe per location and make sure the wipe is identified.

3. Let the wipes air dry.

4. Measure the radioactivity on each wipe using appropriate detection equipment (LS counter, γ counter, survey meter).

5. Do a background count using an uncontaminated wipe.

6. If there is contamination (> 2x bkg.) on any of the wipes, proceed to decontaminate the area. Repeat wipe testing the location and cleaning until contamination is not detectable.

7. **Keep records of results** in binder provided by the Radiation Safety Office.

8. Wipe test on a weekly basis.

9. **REMEMBER THAT THE WIPE TEST EFFICIENCY IS ONLY ABOUT 10% FOR A WET WIPE AND 1% FOR A DRY WIPE.**

When you set up a program, aim to test locations where nuclear substances are used as well as unlikely locations such as door handles, telephone receivers, taps etc..

The best way to use the wipe test is as a qualitative check for contamination. If a wipe indicates contamination above background, clean it. If it is necessary to determine activity present, the accompanying table may be used.
WEEKLY LABORATORY WIPE TEST RESULTS

Principal Investigator:__________________  Permit#:__________________

Room #:______________________________

Type of Counter Used: _________________ LSC

_____________________________ Other ( specify )

Nuclear Substance Used: ________________  Bkg. Count: ________

Date: (D/M/Y): _________________________  Surveyors Initials: ________

Please attach counter printout below:
SAFETY DATA SHEET
HYDROGEN-3 (TRITIUM)  

PHYSICAL DATA:
- Radiation: Beta (β) 100 % abundance
- Energy: Max: 18.6 keV; Avg. 5.7 keV
- Half Life (T2): Physical - 12.3 y
  Biological - 10-12d
  Effective - 10-12d
- Specific Activity: 3.59E + 14 Bq.g⁻¹
- Beta Range: Air - 6 mm
  Water - 0.006 mm

RADIOLOGICAL DATA:
- Exemption Quantity: 1 x 10⁹ Bq
- Radiotoxicity: Slight
- Critical organ: Whole body (water & tissue)
- Exposure routes: Ingestion, inhalation, absorption
- Radiological hazard: External - not a radiological concern
  Internal - primary concern

SHIELDING:
None required

DOSIMETRY REQUIREMENTS
External dosimetry not required; urine bioassay for suspected intake

DETECTION
Liquid scintillation counting

PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS
Lab coats, double gloves

SPECIAL PRECAUTIONS
Avoid skin contamination by double gloving (change outer pair ~ every 20 minutes)

³H Handling Procedures
1. Designate an area for handling ³H and label clearly
2. Do not consume food and/or drink in the laboratory
3. Do not pipette by mouth
4. Cover work surfaces with absorbent liners
5. Use transfer pipettes and spill trays to confine contamination
6. Promptly return stock solutions to storage areas
7. Maintain contamination control by regularly monitoring and promptly cleaning contaminated areas
8. Isolate waste in clearly labeled containers and arrange for disposal with the RSO
9. Maintain cleanliness and good housekeeping in the work area
10. Supervise nuclear substances at all times when in use
11. Keep laboratory locked when unattended
### SAFETY DATA SHEET

#### CARBON-14

<table>
<thead>
<tr>
<th>PHYSICAL DATA:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiation:</strong></td>
<td>Beta (β') - 100% abundance</td>
</tr>
<tr>
<td><strong>Energy:</strong></td>
<td>Max: 156 keV; Avg: 49 keV</td>
</tr>
<tr>
<td><strong>Half Life (T½):</strong></td>
<td>Physical - 5730 yrs</td>
</tr>
<tr>
<td></td>
<td>Biological - 12 d</td>
</tr>
<tr>
<td></td>
<td>Effective - 12 d (bound); 40 d (unbound)</td>
</tr>
<tr>
<td><strong>Specific Activity:</strong></td>
<td>$1.65 \times 10^{11}$ Bq.g$^{-1}$</td>
</tr>
<tr>
<td><strong>Beta Range:</strong></td>
<td>Air: 24 cm.</td>
</tr>
<tr>
<td></td>
<td>Water/Tissue: 0.28 mm</td>
</tr>
<tr>
<td></td>
<td>Plexiglass: 0.3 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RADIOLOGICAL DATA:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exemption Quantity</strong></td>
<td>$1 \times 10^8$ Bq</td>
</tr>
<tr>
<td><strong>Radiotoxicity</strong></td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Critical organ</strong></td>
<td>Fat tissue</td>
</tr>
<tr>
<td><strong>Exposure routes</strong></td>
<td>Ingestion, inhalation, absorption</td>
</tr>
<tr>
<td><strong>Radiological hazard</strong></td>
<td>External - dose to skin from contamination in mSv.h$^{-1} = 3.24 \times 10^{-1}$/kBq.cm$^2$</td>
</tr>
<tr>
<td></td>
<td>Internal - primary concern</td>
</tr>
</tbody>
</table>

| SHIELDING: | 0.75 - 3 mm plexiglass |

| DOSIMETRY REQUIREMENTS: | External dosimetry not required; urine bioassay for suspected intake |

<table>
<thead>
<tr>
<th>DETECTION</th>
<th>Liquid scintillation counting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pancake GM detector - 3.75% efficiency @ cm (2.25% probe protected with saran wrap; 0.06% protected with parafilm)</td>
<td></td>
</tr>
</tbody>
</table>

| PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS: | Lab coats, double gloving |

| SPECIAL PRECAUTIONS | Avoid skin contamination by double gloving (change outer pair ~ every 30 minutes), use remote handling devices where possible |

**$^{14}$C Handling Procedures:**

1. Designate an area for handling $^{14}$C and label clearly
2. Do not consume food and/or drink in the laboratory
3. Do not pipette by mouth
4. Cover work surfaces with absorbent liners
5. Use transfer pipettes and spill trays to confine contamination
6. Promptly return stock solutions to storage areas
7. Maintain contamination control by regularly monitoring and promptly cleaning contaminated areas
8. Isolate waste in clearly labeled containers and arrange for disposal with the RSO
9. Maintain cleanliness and good housekeeping in the work area
10. Supervise nuclear substances at all times when in use
11. Keep laboratory locked when unattended
<table>
<thead>
<tr>
<th>PHYSICAL DATA:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation:</td>
<td>Gamma (γ) - 35.5 keV (7 % abundance)</td>
</tr>
<tr>
<td></td>
<td>X-ray - 27 keV (113 % abundance)</td>
</tr>
<tr>
<td>Specific γ ray constant</td>
<td>0.27 - 7.0 μSv/hr/37 MBq @ 1 m</td>
</tr>
<tr>
<td>Half Life (T₂)</td>
<td>Physical - 60.1 d</td>
</tr>
<tr>
<td></td>
<td>Biological - 120-138 d</td>
</tr>
<tr>
<td></td>
<td>Effective - 42 d</td>
</tr>
<tr>
<td>Specific Activity</td>
<td>6.45E + 14 Bq.g⁻¹</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RADIOLOGICAL DATA:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exemption Quantity</td>
<td>1 x 10⁶ Bq</td>
</tr>
<tr>
<td>Radiotoxicity</td>
<td>High</td>
</tr>
<tr>
<td>Critical organ</td>
<td>Thyroid</td>
</tr>
<tr>
<td>Exposure routes</td>
<td>Inhalation, ingestion, absorption</td>
</tr>
<tr>
<td>Radiological hazard</td>
<td>External - 1.56 - 2.75 mSv/hr @ 1 cm</td>
</tr>
<tr>
<td></td>
<td>Internal - primary concern</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SHIELDING:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>Half Value Layer (HVL)</td>
</tr>
<tr>
<td></td>
<td>Tenth Value Layer (TVL)</td>
</tr>
<tr>
<td></td>
<td>&lt; 1 mm</td>
</tr>
<tr>
<td></td>
<td>&lt; 1 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSIMETRY REQUIREMENTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body TLDs, bioassay requirement if handling &lt; 50 MBq in a fume hood</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DETECTION:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low energy NaI detector</td>
<td></td>
</tr>
<tr>
<td>Wipe test - LS or γ counting</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab coat, double gloves, foot covers (iodination procedures)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPECIAL PRECAUTIONS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid skin contamination by double gloving (change outer pair ~ every 30 minutes), use remote handling devices where possible. Avoid making low pH solutions containing ¹²⁵I to avoid volatilization. Confine as many manipulations as possible to a fume hood that draws at a minimum of 0.5 - 1.0 m/sec</td>
<td></td>
</tr>
</tbody>
</table>

¹²⁵I Handling Precautions

1. Designate an area for handling ¹²⁵I and label clearly
2. Avoid making low pH solutions containing ¹²⁵I to avoid volatilization
3. Confine as many manipulations as possible to a fume hood
4. Do not consume food and/or drink in the laboratory
5. Do not pipette by mouth
6. Cover work areas with absorbent liners
7. Use transfer pipettes and spill trays to confine contamination
8. Promptly return stock solutions to storage areas
9. Maintain contamination control by regularly monitoring and promptly cleaning contaminated areas
10. Isolate waste in clearly labeled containers and arrange for disposal with the RSO
11. Maintain cleanliness and good housekeeping in the work area
12. Supervise nuclear substances at all times when in use
13. Keep laboratory locked when unattended
## SAFETY DATA SHEET

### PHOSPHORUS-32

#### PHYSICAL DATA:

| Radiation:  | Beta (β) 100 % abundance |
| Energy:     | Max: 1.709 MeV; Avg: 0.690 MeV |
| Half Life (T 2 ) | Physical - 14.3d |
|            | Biological - 257d |
|            | Effective - 14.1d |

| Specific Activity | $1.06E + 16 \text{ Bq.g}^{-1}$ |
| Beta Range:       | Air - 610 cm |
|                   | Water/tissue - 0.76 cm |
|                   | Plexiglass - 0.61 cm |

#### RADIOLOGICAL DATA:

| Exemption Quantity | $1 \times 10^4 \text{ Bq}$ |
| Radiotoxicity      | Moderate |
| Critical organ     | Bone |
| Exposure routes    | Ingestion, inhalation, absorption |
| Radiological hazard | External (skin contamination) 87-92 mSv/37 MBq/cm² |
|                     | External (exposure) 7.8 Sv/hr @ surface of 37 MBq sol² |
|                     | Internal - bone receives ~ 20% of internal dose |

#### SHIELDING:

- Shield with 2 cm plexiglass; apply thin lead sheeting to absorb bremsstrahlung if necessary

#### DOSIMETRY REQUIREMENTS

- Whole body and ring TLD = s required

#### DETECTION:

- Pancake GM probe - 22.4% efficient
- Liquid scintillation counting

#### PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS

- Lab coats, double gloving (outer pair changed ~ every 30 minutes), eye protection

#### SPECIAL PRECAUTIONS

- Avoid skin contamination by double gloving and using remote handling tools
- Store $^{32}$P waste behind plexiglass shielding
- Always have a portable survey meter present and turned on (including audio) during handling

### $^{32}$P Handling Procedures

1. Designate an area for handling $^{32}$P and label clearly
2. Place a whole body plexiglass shield on the work area
3. Ensure that both whole body and ring TLD dosimeters are worn at all times when handling $^{32}$P
4. Ensure that a functioning survey meter is available and in the "ON" position during the entire procedure. The audio must also be turned on
5. Do not consume food and/or drink in the laboratory
6. Do not pipette by mouth
7. Cover work surfaces with absorbent liners
8. Use transfer pipettes and spill trays to confine contamination
9. Promptly return stock solutions to storage areas
10. Maintain contamination control by regularly monitoring and cleaning contaminated areas
11. Isolate waste in clearly labeled containers and arrange for disposal with the RSO
12. Water soluble waste may be disposed to the sanitary sewer provided that the dilution criteria as defined by the CNSC is met
13. Maintain cleanliness and good housekeeping in the work area
14. Supervise nuclear substances at all times when in use
15. Keep laboratory locked when unattended
SAFETY DATA SHEET
PHOSPHORUS -33

PHYSICAL DATA:
Radiation: Beta (β) 100 % abundance
Energy:
Max: 249 keV; Avg: 85 keV
Half Life (T₂)
Physical - 25.4 d
Biological - 257 d
Effective - 24.9 d
Specific Activity
5.72E + 15 Bq.g⁻¹
Beta Range:
Air - 50 cm
Water/tissue - 0.06 cm
Plexiglass - 0.05 cm

RADIOLOGICAL DATA:
Exemption Quantity
1 x 10⁶ Bq
Radiotoxicity
Moderate
Critical organ
Bone marrow
Exposure routes
Inhalation, ingestion, absorption
Radiological hazard
External - dose from skin contamination in mSv.h⁻¹ = 8.65E-1/kBq.cm³

SHIELDING:
32 mm plexiglass for stock solutions

DOSIMETRY REQUIREMENTS
None required. Contact RSO for suspected intake

DETECTION
Liquid scintillation counting
Pancake GM probe - ~ 8% efficiency @ 1 cm (7.2% efficient (saran wrap covered); 1.95% efficient (parafilm covered))

PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS
Lab coats, double gloving

SPECIAL PRECAUTIONS
Avoid skin contamination by double gloving (change outer pair ~ every 30 minutes), use remote handling devices

³³P Handling Procedures

1. Designate an area for handling ³³P and label clearly
2. Do not consume food and/or drink in the laboratory
3. Do not pipette by mouth
4. Cover work surfaces with absorbent liners
5. Use transfer pipettes and spill trays to confine contamination
6. Promptly return stock solutions to storage areas
7. Maintain contamination control by regularly monitoring and promptly cleaning contaminated areas
8. Isolate waste in clearly labeled containers and arrange for disposal with the RSO
9. Maintain cleanliness and good housekeeping in the work area
10. Supervise nuclear substances at all times when in use
11. Keep laboratory locked when unattended
### SAFETY DATA SHEET

**SULPHUR-35**

<table>
<thead>
<tr>
<th>PHYSICAL DATA:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation:</td>
<td>Beta (β) - 100 % abundance</td>
</tr>
<tr>
<td>Energy:</td>
<td>Max: 167 keV; Avg: 53 keV</td>
</tr>
<tr>
<td>Half Life (T2)</td>
<td>Physical - 87.4 d</td>
</tr>
<tr>
<td></td>
<td>Biological - 623 d</td>
</tr>
<tr>
<td></td>
<td>Effective - 44 - 76 d</td>
</tr>
<tr>
<td>Specific Activity</td>
<td>1.58E + 15 Bq.g⁻¹</td>
</tr>
<tr>
<td>Beta Range:</td>
<td>Air - 26 cm</td>
</tr>
<tr>
<td></td>
<td>Water/tissue - 0.32 mm</td>
</tr>
<tr>
<td></td>
<td>Plexiglass - 0.25 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RADIOLLOGICAL DATA:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exemption Quantity</td>
<td>1 x 10⁸ Bq</td>
</tr>
<tr>
<td>Radiotoxicity</td>
<td>Moderate</td>
</tr>
<tr>
<td>Critical organ</td>
<td>Whole body, testes</td>
</tr>
<tr>
<td>Exposure routes</td>
<td>Inhalation, ingestion, absorption</td>
</tr>
<tr>
<td>Radiological hazard</td>
<td>External - negligible</td>
</tr>
<tr>
<td></td>
<td>Internal - primary concern</td>
</tr>
</tbody>
</table>

| SHIELDING: | 3 mm plexiglass for stock solutions |
| DOUMETRY REQUIREMENTS: | None required. Contact RSO for suspected uptake |

| DETECTION: | Liquid scintillation counting |
| Pancake GM probe | 4-6 % efficiency @ 1cm |

| PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS: | Lab coats, double gloving |

<table>
<thead>
<tr>
<th>SPECIAL PRECAUTIONS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid skin contamination by double gloving (change outer pair ~ every 30 minutes). Use remote handling devices where possible.</td>
<td></td>
</tr>
<tr>
<td>Many ³⁵S compounds are slightly volatile. This can occur when ³⁵S amino acids are thawed, and when added to cell culture media and incubated.</td>
<td></td>
</tr>
</tbody>
</table>

³⁵S Handling Procedures

1. Designate an area for handling ³⁵S and label clearly  
2. Do not consume food and/or drink in the laboratory  
3. Do not pipette by mouth  
4. Cover work surfaces with absorbent liners  
5. Use transfer pipettes and spill trays to confine contamination  
6. Handle potentially volatile compounds (particularly ³⁵S methionine and cysteine) in ventilated enclosures  
7. Vent ³⁵S amino acid stock vials with an open ended charcoal filled disposable syringe  
8. Incubators used with ³⁵S should have an activated charcoal trap placed inside  
9. Promptly return stock solutions to storage areas  
10. Maintain contamination control by regularly monitoring and promptly cleaning contaminated areas  
11. Isolate waste in clearly labeled containers and arrange for disposal with the RSO  
13. Supervise nuclear substances at all times when in use  
14. Keep laboratory locked when unattended

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<table>
<thead>
<tr>
<th>SAFETY DATA SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHROMIUM-51</td>
</tr>
</tbody>
</table>

| 51Cr |

### PHYSICAL DATA:
- **Radiation:**
  - Gamma (γ) 320 keV (9.8 % abundance)
  - X-ray - 5 keV (22 % abundance)
- **Specific γ ray constant:** 0.17 μSv/37 MBq @ 1 m
- **Half Life (T2):**
  - Physical - 27.8 d
  - Biological - 616 d
  - Effective - 26.6 d
- **Specific Activity:** \(3.42 \times 10^{15}\) Bq·g\(^{-1}\)

### RADIOLOGICAL DATA:
- **Exemption Quantity:** \(1 \times 10^6\) Bq
- **Radiotoxicity:** Moderate
- **Critical organ:** Lower large intestine (LLI)
- **Exposure routes:** Ingestion, inhalation, absorption
- **Radiological hazard:**
  - External - 16 mSv/hr/37 MBq @ 1 cm
  - Internal - concern

### SHIELDING:

<table>
<thead>
<tr>
<th>Material</th>
<th>Half Value Layer (HVL)</th>
<th>Tenth Value Layer (TVL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>2mm</td>
<td>7 mm</td>
</tr>
<tr>
<td>Concrete</td>
<td>2.8 cm</td>
<td>9.3 cm</td>
</tr>
<tr>
<td>Steel</td>
<td>21 cm</td>
<td>50 cm</td>
</tr>
</tbody>
</table>

*The accessible dose rate should not exceed 2.5 μSv/hr*

### DOSIMETRY REQUIREMENTS:
- Whole body TLDs

### DETECTION:
- Survey meter equipped with a NaI detector

### PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS:
- Lab coats, double gloving

### SPECIAL PRECAUTIONS:
- Avoid skin contamination by double gloving (change outer pair ~ every 30 minutes), use remote handling devices where possible
- Store 51Cr waste behind lead shielding sufficient to reduce dose rate to < 2.5 μSv/h

### 51Cr Handling Procedures:
1. Designate an area for handling 51Cr and label clearly
2. Do not consume food and/or drink in the laboratory
3. Do not pipette by mouth
4. Cover work surfaces with absorbent liners
5. Use transfer pipettes and spill trays to confine contamination
6. Promptly return stock solutions to storage areas
7. Maintain contamination control by regularly monitoring and cleaning contaminated areas
8. Isolate waste in clearly labeled containers and arrange for disposal with the RSO
9. Maintain cleanliness and good housekeeping in the work area
10. Supervise nuclear substances at all times when in use
11. Keep laboratory locked when unattended
**SAFETY DATA SHEET**  
**INDIUM - 111**

### PHYSICAL DATA:
- **Radiation:** Gamma (γ) 245 keV (94% abundance); 171 keV (90% abundance); 23 keV (69% abundance)

<table>
<thead>
<tr>
<th>Specific γ ray constant</th>
<th>9.9E-4 @ 30 cm from 1 MBq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half Life (T 2)</td>
<td>Physical - 2.80 d</td>
</tr>
<tr>
<td>Specific Activity</td>
<td>1.55E + 16 Bq⁻¹</td>
</tr>
</tbody>
</table>

### RADIOLOGICAL DATA:
- **Exemption Quantity:** 1 x 10⁵ Bq
- **Radiotoxicity:** Moderate
- **Critical organ:** Lower large intestine (LLI)
- **Exposure routes:** Ingestion, inhalation, absorption
- **Radiological hazard:** External - contamination skin dose in mSv.h⁻¹ = 3.78E⁻¹/kBq/cm²

### SHIELDING:
- **Half Value Layer (HVL)**
  - Lead: < 1mm
  - Steel: 9 mm
- **Tenth Value Layer (TVL)**
  - Lead: 3 mm
  - Steel: 31 mm

> *The accessible dose rate should not exceed 2.5 μSv/hr*

### DOSIMETRY REQUIREMENTS:
Whole body TLD=s required

### DETECTION:
Pancake GM detector

### PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS:
Lab coats, double gloving

### SPECIAL PRECAUTIONS
Avoid skin contamination by double gloving (change outer pair ~ every 30 minutes), use remote handling devices where possible. Store ¹¹¹In waste behind sufficient lead shielding to reduce exposure rates to < 2.5 μSv/hr.

**¹¹¹In Handling Procedures**

1. Designate an area for handling ¹¹¹In and label clearly
2. Do not consume food and/or drink in the laboratory
3. Do not pipette by mouth
4. Cover work surfaces with absorbent liners
5. Use transfer pipettes and spill trays to confine contamination
6. Promptly return stock solutions to storage areas
7. Maintain contamination control by regularly monitoring and promptly cleaning contaminated areas
8. Isolate waste in clearly labeled containers and arrange for disposal with the RSO
9. Maintain cleanliness and good housekeeping in the work area
10. Supervise nuclear substances at all times when in use
11. Keep laboratory locked when unattended
**SAFETY DATA SHEET**

**TECHNETIUM-99M**

<table>
<thead>
<tr>
<th><strong>PHYSICAL DATA:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation:</td>
<td>Gamma (γ) 141 keV (89% abundance)</td>
</tr>
<tr>
<td>Specific γ ray constant</td>
<td>7.7 mSv/hr @ 1 cm from a 37 MBq source</td>
</tr>
<tr>
<td>Half Life (T₂)</td>
<td>Physical - 6 h</td>
</tr>
<tr>
<td></td>
<td>Biological - ~ 1 d</td>
</tr>
<tr>
<td></td>
<td>Effective - ~ 4.8 h</td>
</tr>
<tr>
<td>Specific Activity</td>
<td>1.95E + 17 Bq.g⁻¹</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>RADIOLOGICAL DATA:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exemption Quantity</td>
<td>1 x 10⁷ Bq</td>
</tr>
<tr>
<td>Radiotoxicity</td>
<td>Moderate</td>
</tr>
<tr>
<td>Critical organ</td>
<td>Thyroid</td>
</tr>
<tr>
<td>Exposure routes</td>
<td>Ingestion, inhalation, absorption</td>
</tr>
<tr>
<td>Radiological hazard</td>
<td>External - 2.46E-1 mSv.h⁻¹ /1 kBq.cm²</td>
</tr>
<tr>
<td></td>
<td>Internal hazard</td>
</tr>
</tbody>
</table>

| **SHIELDING:** |  |  |
|----------------|-------------------------|
| Lead           | Half Value Layer (HVL) |
|                | < 1 mm                  |
|                | Tenth Value Layer (TVL) |
| Steel          | 1 mm                    |
|                | 19 mm                   |

* The accessible dose rate should not exceed 2.5 μSv/hr

<table>
<thead>
<tr>
<th><strong>DOSEMETRY REQUIREMENTS</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body and ring TLD=s are required</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>DETECTION</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pancake GM detector</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab coats, double gloving</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>SPECIAL PRECAUTIONS</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid skin contamination by double gloving (change outer pair ~ every 30 minutes), use remote handling devices where possible. Store ⁹⁹ᵐTc behind sufficient lead shielding to reduce exposure to &lt; 2.5 μSv/hr</td>
<td></td>
</tr>
</tbody>
</table>

---

**⁹⁹ᵐTc Handling Procedures**

1. Designate an area for handling ⁹⁹ᵐTc and label clearly
2. Do not consume food and/or drink in the laboratory
3. Do not pipette by mouth
4. Cover work surfaces with absorbent liners
5. Use transfer pipettes and spill trays to confine contamination
6. Promptly return stock solutions to storage areas
7. Maintain contamination control by regularly monitoring and promptly cleaning contaminated areas
8. Isolate waste in clearly labeled containers and arrange for disposal with the RSO
9. Maintain cleanliness and good housekeeping in the work area
10. Supervise nuclear substances at all times when in use
11. Keep laboratory locked when unattended
GLOSSARY OF TERMS

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.

Bioassay

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 woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Decontamination

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
That 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

**NONS**

Naturally occurring nuclear substance

**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

1895   Roentgen discovers x-rays
1896   Becquerel discovers nuclear radiation
1898   Discovery of radioactivity by Marie & Pierre Curie
1899   Rutherford recognizes three types of nuclear radiation
1900   American Roentgen Ray Society (ARRS) founded
1902   First proposal to limit exposure
1913   First radiotracer experiment
1915   British Roentgen Society adopted x-ray protection resolution;
1920   ARRS established standing committee for radiation protection
1921   British X-ray & Radium Protection Committee presented its first radiation protection rules
1922   American Registry of X-Ray Technicians founded
1925   Specific skin dose limit proposed
1925   First International Congress of Radiology, London, established ICRU
1927   Demonstration of the genetic effects of radiation
1928   ICRP established under the auspices of the Second International Congress of radiology, Stockholm
1928   ICRU adopted the Roentgen as the unit of exposure
1929   Advisory Committee on X-ray and Radium Protection (ACXRP) formed in the US, a forerunner of NCRP
1931   ACXRP published recommendations (National Bureau of Standards Handbook 15)
1934   ICRP recommended a daily tolerance dose
1936   Reduction of limit to 0.1 R/day
1941   ACXRP recommended first permissible body burden, for radium
1942   Manhattan project began to develop atomic bomb
1942   Birth of Health Physics as a profession
1946   U.S. Atomic Energy Commission (AEC) created
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

**REVIEW QUESTIONS**
( fill in or select the correct response )

1. The three components of the atom are: ________________, ________________, and ________________.

2. ________________ have equal numbers of protons but different numbers of neutrons in the nucleus.

3. A __________ is an electron-like particle emitted from the nucleus of a radioactive atom.

4. The ____________ is the amount of time required for a quantity of nuclear substance to decrease to one-half of its original amount.

5. One becquerel (Bq) is equivalent to ________________ disintegrations per second.

6. Low energy beta emitters (\(^{3}\)H, \(^{14}\)C, \(^{33}\)P, \(^{35}\)S ) are ____ are not ____ external hazards.

7. All labs using nuclear substances must have a ________________ ________________ posted on the door.

8. The average annual radiation dose attributable to natural background in Halifax is approximately ________________ mSv/year.

9. The maximum hand/wrist dose for occupationally exposed workers at Dalhousie University is ________________ mSv/year.

10. The annual whole body dose limit for an occupationally exposed worker at Dalhousie University is ________________ mSv/year.

11. The maximum dose limit for the fetus is ________________ mSv in 9 months.

12. The three basic principles in radiation protection are: __________, __________, and __________.

13. Shield gamma emitters with ________________.

14. Lucite is the best material to shield beta emitters. True/False.

15. Do/Do Not eat, drink, smoke, mouth pipette in a radiation work area.

16. It is acceptable to store food and beverage in refrigerators that contain radioactive materials. True/False

17. After working with radioactive materials, you should monitor your work are, then __________ and monitor your hands before you leave the laboratory.

18. Do/Do not work with radioactive materials if you have an open cut.

19. Always perform radiation work on a ______________________ which is capable of containing the entire volume of a liquid radioactive material spill.

20. If you are contaminated with radioactivity, ________________ the contaminated area with
and ________ water, then contact Radiation Safety.

21. Disposable gloves will stop all beta particles from $^{35}$S. **True/False**

22. Prior to opening a radioactive shipment package, first put on ________.

23. Before discarding an empty nuclear substance shipment box, ________ for contamination and if clean ________ the radiation warning sign.

24. Short lived (T2 < 90 days) nuclear substances may be held for decay prior to disposal. Radioactive decay ensures that after ________ half-lives, only 0.1% of the original activity will remain.

25. In general full laboratory contamination surveys are required **weekly ____, bi-weekly ____**, **monthly _____.**

26. A wipe test is a survey for ________ contamination.

27. The wipe test efficiency is approximately _______%.

28. The action level for removable $^{32}$P contamination is _______ cpm/cm3.

29. Work with volatile radioiodine, $^{35}$S etc.. should be performed in a ________.

30. A ________ probe is used to survey for contamination after working with radioiodine.

31. Thawing $^{35}$S amino acid vials in a fume hood with a needle stuck through the rubber septum may reduce contamination. **True/False**

32. Immediately following a radioactive spill, take precautions to ________ the material.

33. For all spills, ________ all individuals involved for contamination. **True/False**

34. After decontaminating a spill, prepare a ________ of the spill and cleanup and submit to Radiation Safety.

35. When decontaminating equipment, change your gloves ________ to prevent skin contamination through rips and tears.

36. Decontaminate spills to a maximum target level of ________ above background.

37. Liquid scintillation counters are ideal for counting ________ emitting radionuclides.

38. Wear the whole body dosimeter between your ________ and ________.

39. It is permissible to share a single personal dosimeter with a colleague as long as you are both working on a radiation project together. **True/False**
40. What type of bioassay would be used to determine the internal dose by an intake of radioiodine:
   a) whole body scan
   b) urinalysis
   c) thyroid count
   d) none of the above

41. The first operational check to be performed on a survey meter is a _______ check.

42. A background count should be performed, prior to your survey, in an area of known ________________ background.

43. When performing a wipe test you should normally wipe an area of approximately ________________ cm$^2$. at each identified location.

44. Survey records must be kept for a minimum of ________ years.

45. Personal dosimeters are required to be issued to persons handling only $^3$H, $^{14}$C, $^{35}$S.
   True/False

46. For detecting low energy beta particles, a pancake GM detector is normally less _____ more ______ sensitive than an end window detector.

47. Which safety measures are necessary for protection from gamma or high energy beta emitting nuclear substances:
   a) time
   b) distance
   c) shielding
   d) contamination control
   e) all of the above

48. The handling and management of liquid scintillation vials and their contents includes:
   a) disposal down sanitary sewer
   b) holding for decay of nuclear substance
   c) disposing as solvent waste
   d) none of the above

49. Radiation workers are responsible for following safe work practices and:
   a) performing work in authorized locations only
   b) maintaining monitoring records
   c) following approved procedures
   d) notifying the RSO of unsafe conditions
   e) all of the above
50. Which type of bioassay would be used to determine the internal dose received by an intake of tritium:
   a) thyroid count
   b) whole body count
   c) urinalysis
   d) all of the above
   e) none of the above

51. Identify the required data for the following nuclear substances:

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Emission (α,β,γ)</th>
<th>T 2</th>
<th>Radiotoxicity</th>
<th>Exemption Quantity</th>
<th>Shielding</th>
<th>Detection</th>
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<tr>
<td>$^3$H</td>
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<tr>
<td>$^{14}$C</td>
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<td></td>
<td></td>
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<tr>
<td>$^{125}$I</td>
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<td>$^{35}$S</td>
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</tr>
<tr>
<td>$^{51}$Cr</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

52. ALARA is an acronym standing for ____________________________.

53. Dalhousie University has a Compliance Enforcement Policy® for nuclear substance users. Listed are a sampling of offences that are frequently encountered. Identify the following offences as either major or minor:
   a) contamination above licence criteria
   b) inadequate monitoring program
   c) inappropriate use of warning labels
   d) inadequate posting
   e) inadequate inventory records
   f) use/storage of food/drink in lab
   g) inadequate signage
   h) non participation in bioassay programs
   i) inadequate staff training

54. The federal agency responsible for the control of the use of radioisotopes in Canada is:
   a) Radiation Protection Bureau
   b) Nuclear Regulatory Commission
   c) Atomic Energy of Canada Limited
   d) Canadian Nuclear Safety Commission
55. The Canadian Nuclear safety Commission does have the authority to issue a stop work orders if a work situation is deemed unsafe. True/False

56. Nuclear Substance User Permits are issued to Dalhousie University researchers by:
   a) Canadian Nuclear Safety Commission
   b) Dalhousie University Radiation Safety Committee

57. The critical or target organ for the following radioisotopes are:
   a) $^{125}$I
   b) $^{32}$P
   c) $^{3}$H
   d) $^{14}$C
   e) $^{35}$S

58. It is acceptable to throw used lead/plastic pigs into the regular laboratory waste. True/False

59. Radioisotope purchases orders can be placed by:
   a) Principal Investigator
   b) Graduate Student
   c) Purchasing Agent
   d) All of the above
   e) None of the above

60. The Radiation Safety Officer at Dalhousie University is ________________.

Review Questions - Answers
1. Neutron, proton, electron
2. Isotopes
3. Beta particle
4. Half-Life
5. One
6. Are not
7. Radiation warning sign
8. One
9. 75
10. 5
11. Not to exceed 4 mSv
12. Time, distance, shielding
13. Lead
14. True
15. Do not
16. False
17. Wash
18. Do not
19. Spill tray lined with absorbent paper
20. Wash, soap, tepid
21. True
22. Gloves
23. Monitor, deface
24. Ten
25. Weekly
26. Loose
27. 10%
28. 200
29. Fume hood
30. NaI
31. True
32. Contain
33. Monitor
34. Report
35. Often
36. Twice
37. Beta
38. Neck, waist
39. False
40. C
41. Battery
42. Low
43. 100
44. 5
45. False
46. More
47. E
48. C
49. E
50. C

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Emission (α, β, γ)</th>
<th>T²</th>
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<th>Exemption Quantity</th>
<th>Shielding</th>
<th>Detection</th>
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<tr>
<td>³⁵Cl</td>
<td>beta</td>
<td>12.3 yrs</td>
<td>slight</td>
<td>1 x 10⁹ Bq</td>
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<td>5730 yrs</td>
<td>moderate</td>
<td>1 x 10⁹ Bq</td>
<td>0.75-3 mm lucite</td>
<td>LS counting Pancake GM probe</td>
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<tr>
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<td>gamma</td>
<td>60.1 days</td>
<td>high</td>
<td>1 x 10⁹ Bq</td>
<td>lead</td>
<td>low energy NaI detector</td>
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<td>moderate</td>
<td>1 x 10⁶ Bq</td>
<td>pleiglass</td>
<td>LS count, Pancake GM probe</td>
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<td>³²P</td>
<td>beta</td>
<td>25.4 days</td>
<td>moderate</td>
<td>1 x 10⁶ Bq</td>
<td>pleiglass (stock)</td>
<td>LS count, Pancake GM probe</td>
</tr>
<tr>
<td>³⁵S</td>
<td>beta</td>
<td>87.4 days</td>
<td>moderate</td>
<td>1 x 10⁶ Bq</td>
<td>pleiglass (stock)</td>
<td>LS count, Pancake GM probe</td>
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<tr>
<td>⁵¹Cr</td>
<td>gamma</td>
<td>27.8 days</td>
<td>moderate</td>
<td>1 x 10⁹ Bq</td>
<td>lead</td>
<td>meter with NaI probe</td>
</tr>
</tbody>
</table>

52. As low as reasonably achievable
53. Major, major, minor, minor, major, minor, major, major
54. D
55. True
56. B
57. Thyroid, bone, body fluid, fatty tissue, testes/whole body
58. False
59. C
60. Pauline Jones
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