Radiation Safety Guide

University of Ottawa

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CHAPTER IV: APPENDICES

1. ABOUT THE RADIATION SAFETY MANUAL

The University of Ottawa Radiation Safety Manual has been prepared in order to:

- acquaint users of radioisotopes with the policies and procedures of the University of Ottawa;
- ensure that all radioisotope users follow safe laboratory practices and can respond to emergency situations; and
- fulfill the requirements under the University of Ottawa Consolidated Radioisotope License find as issued by the Canadian Nuclear Safety Comission.

The Radiation Safety Manual has been prepared by the Environmental Health and Safety Service. The Service is responsible for reviewing and updating this manual. Any questions or comments should be addressed to the Environmental Health and Safety Service (EHSS) at 562-5892.

The manual is divided into four chapters which are separated by large tabs:

- CHAPTER I: POLICIES;
- CHAPTER II: PROCEDURES;
- CHAPTER III: GENERAL INFORMATION; and
- CHAPTER IV: APPENDICES.

Certain sections of the manual are specific to sealed source or open source work. Individuals involved with the use of radioisotopes should consult the sections as outlined in **Table 1**.

TABLE 1. WHICH SECTIONS SHOULD YOU READ?			
	CHAPTER I SECTIONS	CHAPTER II SECTIONS	CHAPTER III SECTIONS
Open Source Permit Holders	1, 2, 3, 4.3, 5	6, 7, 8, 9, 10.2, 11, 12, 13, 14, 15, 16.3, 17.2, 18, 19	20, 21, 22, 23, 24, 25, 26, 27, 28
Open Source Users	1, 2, 3, 4.4, 5	6, 10, 11, 13, 14, 15.2, 16.3, 17.2, 18	20, 21, 22, 23, 24, 25, 26, 27, 28
Sealed Source Permit Holders	1, 2, 3, 4.3, 5	6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19	20, 21, 22, 23, 24, 25, 26, 27, 28
Sealed Source Users	1, 2, 3, 4.4, 5	6, 11, 13, 18	20, 21, 22, 23, 24, 25, 26, 27, 28

2. DEFINITIONS

ACCURACY - Accuracy is an expression of the correctness of a measurement when compared to the *true value* of the quantity being measured. Radioactive decay is a random phenomenon hence the *true value* cannot be stated. It is preferable to refer to UNCERTAINTY in a measurement, of radioactivity. (See also PRECISION)

CNSC - The Canadian Nuclear Safety Comission. This agency regulates all use of radioisotopes in Canada.

ALARA - As **L**ow **A**s **R**easonably **A**chievable. This concept is the fundamental basis of radiation safety. Exposure to radiation should be limited by using time, distance and shielding as outlined in Section 21.

ALPHA PARTICLE - [Symbol:- (alpha)] A doubly positively-charged particle emitted by certain radioactive materials. It is made up two neutrons and two protons bound together, hence is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, being stopped by a sheet of paper. It is not dangerous to plants, animals or man unless the alpha-emitting substance has entered the body. (See DECAY, RADIOACTIVE)

AMPLIFICATION - The change in amplitude of a signal, i.e., increase of amplitude of pulses from the PMTs. In liquid scintillation counting, amplification also refers to a decrease in pulse amplitude.

AUGER ELECTRON - An electron originating in the cloud of electrons surrounding a nucleus that has acquired sufficient energy to break away from the nucleus. An Auger electron is produced when an inner shell electron is removed by mechanisms such as electron capture and an outer shell electron loses energy to fill the vacancy. The excess energy is frequently transferred to another outer electron of the atom which then breaks away and becomes an Auger electron with a kinetic energy equal to the excess energy minus the electron's binding energy.

AUTOMATIC EFFICIENCY CONTROL (AEC) - A method used by the Tri-Carb liquid scintillation analyzer to compensate for the effect of quenching on the sample spectrum. AEC extracts from the Spectralyzer spectrum analyzer the equivalent keV data for the region entered into the measurement program. AEC is based on SIE or tSIE.

BACKGROUND RADIATION - The radiation in man's natural environment including cosmic rays from space and radiation from radionuclides present in the local environment. Sources of the latter include materials of construction, e.g., metals, glasses, ceramics and concrete.

BECQUEREL - [Symbol: Bq] The basic unit of radioactivity in the International System of Units. One becquerel is equal to one disintegration per second. Since one curie is 3.7×10^{10} dps, it is also 3.7×10^{10} becquerels. (See Section 22.1.)

BETA PARTICLE - [Symbol: (beta)] An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

BIOLOGICAL HALF-LIFE - [Symbol: T_b] The time required for a biological system such as a man or an animal, to eliminate, by natural processes, half the amount of a substance (such as radioactive material). (Compare HALF-LIFE)

CERENKOV RADIATION - Light emitted when charged particles pass through a transparent material at a velocity greater than that of light in that material. It can be seen, for example, as a blue glow in the water around the fuel elements of pool reactors. Pavel A. Cerenkov was the Russian scientist who first explained the origin of this light.

CHEMILUMINESCENCE - Random single photon events which are generated as a result of the chemical interaction of sample components. The coincidence circuit excludes most chemilumine scent events except at high rates.

CHEMICAL QUENCHING - A reduction in the scintillation intensity seen by the photomultiplier tubes due to materials present in the scintillation solution that interfere with the processes leading to the production of light. The result is fewer photons per keV of beta particle energy and usually a reduction in counting efficiency. (Also refer to OPTICAL and QUENCHING)

CHI-SQUARE TEST - A general procedure for determining the probability that two different distributions are actually samples of the same population. In nuclear counting measurements, this test is frequently used to compare the observed variations in repeat counts of a radioactive sample with the variation predicted by statistical theory.

COCKTAIL - The solution in which samples are placed for measurement in a liquid scintillation counter. Solvents and scintillators are the major components of a scintillation cocktail.

COEFFICIENT OF VARIATION (C.V.) - The ratio of the standard deviation of a distribution to its arithmetic mean.

COLLISION - A close approach of two or more particles, photons, atoms or nuclei, during which such quantities as energy, momentum and charge may be exchanged.

COINCIDENCE RESOLVING TIME - The maximum time interval allowed between two or more input signals for the production of an output signal. Input signals separated by more than the coincidence resolving time produce no output signal. The coincidence resolving time of Tri-Carb spectrometers is approximately 20×10^{-9} second.

COINCIDENCE CIRCUIT - A portion of the electronic analysis system of the liquid scintillation counter which acts to reject pulses which are not received from the two PMTs within the COINCIDENCE RESOLVING TIME.

COINCIDENCE THRESHOLD - The minimum decay energy required for a liquid scintillation counter to detect a radioactive event. It is approximately 1/3 keV when the sample being measured is unquenched.

COMPENSATED REGIONS - Regions that are compensated for different levels of quenching. (Also refer to AUTOMATIC EFFICIENCY CONTROL)

COMPTON EFFECT - Elastic scattering of photons (x-ray or gamma ray) by electrons. In each such process the electron gains energy and recoils, and the photon loses energy. This is one of three ways photons lose energy upon interacting with matter, and is the usual method with photons of intermediate energy and materials of low atomic number. It is named for Arthur H. Compton, American physicist, who discovered it in 1923.

CONTAMINATION - CNSC defines contamination as 5 Bq/cm^2 of beta and gamma radiation averaged over an area not exceeding 100 cm^2. (See Section 14.3.3.)

COSMIC RAYS - Radiation of many sorts, but mostly atomic nuclei (protons) with very high energies, originating outside the earth's atmosphere. Cosmic radiation is part of the natural background radiation. Some cosmic rays are more energetic than any man-made forms of radiation.

COUNTER - A general designation applied to radiation detection instruments that measure radiation in terms of individual ionizations, displaying them either as the accumulated total or their rate of occurrence.

CURIE - [Symbol: Ci] A basic unit of radioactivity. The curie is equal to 3.7×10^{10} disintegrations per second, which is approximately the rate of decay of I gram of radium. A curie is also a quantity of any nuclide having 1 curie of radioactivity. Named for Marie and Pierre Curie, who discovered radium in 1898. (See BECQUEREL)

DAUGHTER - A nuclide, stable or radioactive, formed by radioactive decay of a PARENT.

DEAD TIME - The length of time immediately following the sensing of a signal pulse that the instrument remains insensitive and unable to process another pulse.

DECAY, RADIOACTIVE - The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in a decrease, with time, of the number of original radioactive atoms in a sample. It involves the emission from the nucleus of alpha particles, beta particles, or gamma rays; or the nuclear capture or ejection of orbital electrons; or fission. Also called radioactive disintegration.

DECONTAMINATION - The removal of radioactive contaminants from surfaces or equipment by cleaning and washing with a solvent or chemical.

DETECTOR - Material or a device that is sensitive to radiation and can produce a response signal suitable for measurement or analysis. A radiation detection instrument.

DISCRIMINATOR - An electronic circuit which distinguishes signal pulses according to their pulse height or voltage. It is used to exclude extraneous radiation counts or background radiation, or as the basis for pulse height analysis.

DISINTEGRATION - See DECAY.

DPM - Disintegrations Per Minute.

DUAL LABEL - Two different radionuclides in a sample.

EFFECTIVE HALF-LIFE - (Symbol:- T_{eff}] The time required for a radioactive element in a biological system, such as man or an animal, to be reduced by one-half as a result of the combined action of radioactive decay and biological elimination.

EFFICIENCY - The ratio of measured observations (i.e. counts) to the number of decay events which occurred during the measurement time. It is usually expressed as a percentage.

EFFICIENCY CORRELATION - The relationship between the measuring efficiency in a region of analysis and the quench indicating parameter. (QIP)

EFFICIENCY TRACING - A technique which uses spectral distribution analysis to calculate absolute activities of the sample at 100% efficiency.

ELECTROMAGNETIC RADIATION - A general term to describe an interacting electric and magnetic wave that propagates through vacuum at the speed of light. It includes radio waves, infrared light, visible light, ultraviolet light, x-rays and gamma rays.

ELECTRON - [Symbol: e^-] An elementary particle with a unit negative electrical charge and a mass 1/1837 that of the proton. Electrons surround the positively charged NUCLEUS and determine the chemical properties of the atom. Positive electrons, or POSITRONS, also exist.

ELECTRON CAPTURE (EC) - A mode of radioactive decay of a nuclide in which an orbital electron is captured by and merges with the nucleus, thus forming a new nuclide with the mass number unchanged, but the atomic number decreased by 1. (See K-CAPTURE)

ELECTRON VOLT - [Symbol: eV] The amount of kinetic energy gained by an electron when it is accelerated through an electric potential difference of 1 volt. It is equivalent to 1.603×10^{-12} erg. It is a unit of energy, or work, not of voltage.

EXCITED STATE - The state of molecule, atom, or nucleus when it possesses more than its normal energy. Excess molecular or atomic energy may appear as light or heat. Excess nuclear energy is often released as a gamma ray.

EXTERNAL STANDARD - A radioactive source placed adjacent to the liquid sample to produce scintillations in the sample for the purpose of monitoring the sample's level of quenching. The external standard is commonly ^{116}Ra, ^{137}Cs or ^{133}Ba.

EXTERNAL STANDARD RATIO (ESR) - The ratio of the counts produced in two channels of pulse-height analysis when a sample is irradiated with an external standard source. It is used as an indicator of the level of quenching in the scintillation solution.

FIGURE OF MERIT - A term applied to a numerical value used to characterize the performance of a system. In liquid scintillation counting, specific formulas have been derived for quantitatively comparing certain aspects of counter performance and cocktail performance.

FLUORESCENCE - The emission of light resulting from the absorption of incident radiation and persisting only as long as the stimulating radiation is continued.

FULL SPECTRUM DPM - Advanced spectrum analysis technique used to separate the individual radionuclide spectra in dual-labeled samples to calculate DPM results.

GAIN CONTROL - A control used to adjust the height of a pulse received from the detecting system.

GAMMA RAYS - [Symbol: (gamma)] High energy, short-wavelength electromagnetic radiation originating in the nucleus of an atom. Gamma rays are very penetrating and are best stopped by dense materials, such as lead or depleted uranium. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission.

GROSS COUNTS - The total number of counts accumulated in the established counting region during the measuring period.

GROUND STATE - The state of a nucleus, atom, or molecule at its lowest (normal) energy level.

HALF-LIFE - [Symbol: $T_{1/2}$] The time in which one-half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years. (Ssee Sections 16 and 20.)

HALF-THICKNESS - The thickness of any given absorber that will reduce the intensity of a beam of radiation to one-half its initial value.

INTENSITY (Radiant beam) - The amount of energy, the number of photons, or the number of particles of any radiation incident upon a unit area per unit time.

INTERNAL STANDARD - A known amount of radioactivity which is added to a sample in order to determine the counting efficiency of that sample. The radionuclide used must be the same as that which is in the sample.

ION - An atom or molecule that has lost or gained one or more electrons. By this ionization it becomes electrically charged. Examples: 1) an alpha particle, which is a helium atom minus two electrons, 2) a proton, which is a hydrogen atom minus its electron.

IONIZATION - The process of adding one or more electrons to, or removing one or more electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges or nuclear radiations can cause ionization.

IONIZING RADIATION - Any radiation displacing electrons from atoms or molecules, thereby producing ions. Examples: alpha, beta, gamma radiations, short-wave ultraviolet light. Ionizing radiation may produce severe skin or tissue damage.

IPA (Integrated Photomultiplier tube Assembly) - A combination of a conventional PMT and a portion of the associated electronics in a single package.

ISOTOPE - One of two or more atoms with the same atomic number (the same chemical element) but with different atomic weights. An equivalent statement is that the nuclei of isotopes have the same number of protons but different numbers of neutrons. Thus, ^{13}C and ^{14}C are isotopes of the element carbon (the superscript denoting the differing mass numbers) of approximate atomic weights. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties. (See NUCLIDE)

K-CAPTURE - The capture by an atomic nucleus of an orbital electron from the first (innermost) orbit or K-shell, surrounding the nucleus.

keV (kiloelectron Volt) - One thousand electron volts.

KILO - [Symbol: k] A prefix that multiplies a basic unit by 10^3.

KINETIC ENERGY - The energy which a body possesses by virtue of its motion. In classical mechanics, it is one-half the product of mass times the square of velocity.

LIMIT OF DETECTION - The minimum amount of the characteristic property being measured that can be detected with reasonable certainty by the analytical procedure being used. The term "sensitivity" is sometimes incorrectly used to mean LIMIT OF DETECTION.

LINEAR AMPLIFICATION - A form of pulse modification which increases the height of all pulses by a common factor. This preserves the relative height of all pulses.

LIQUID SCINTILLATION ANALYZER - A liquid scintillation counter which stores the complete sample spectrum and uses applied spectrum analysis to calculate count rates or disintegrations per minute (absolute activity).

LOGARITHMIC AMPLIFICATION - A form of pulse modification in which pulse height is made proportional to the logarithm of the original height. This form of amplification does not preserve the relative height of all pulses.

LOWER LIMIT - Defines lower energy level of a region or channel.

LUMINESCENCE - A general term applied to the emission of light by causes other than high temperature. Light produced by the latter cause is called incandescence.

MASS NUMBER - The sum of the neutrons and protons in a NUCLEUS. It is the nearest whole number to an atom's atomic weight. For instance, the mass number of ^{235}U is 235.

MEAN - The average of a list of numbers.

MEGA - [Symbol: M] A prefix that multiplies a basic unit by 10^6.

MeV (Megaelectron Volts) - One million electron volts.

MICRO - [Symbol: μ] A prefix that divides a basic unit by 10^6.

NANO - [Symbol: n] A prefix that divides a basic unit by 10^9.

NET COUNTS - The total counts minus the background counts during the sample counting time.

NEUTRINO - [Symbol: (nu)] An electrically neutral elementary particle with a negligible mass. It interacts very weakly with matter and hence is difficult to detect. It is produced in many nuclear reactions, for example, in beta decay, and has high penetrating power. Neutrinos from the sun usually pass right through the earth.

NEUTRON - [Symbol: n] An uncharged elementary particle with mass slightly greater than that of the proton, and found in the nucleus of every atom heavier than hydrogen. A free neutron is unstable and decays with half-life of about 13 minutes into an electron, proton and neutrino. Neutrons sustain the fission chain reaction in a nuclear reactor.

NUCLEUS - The small, positively charged core of an atom. It is only about 1/10,000 the diameter of the atom, but contains nearly all the atom's mass. All nuclei contain both protons and neutrons, except the nucleus of ordinary hydrogen, which consists of a single proton.

NOISE PULSE - A spurious signal appearing in the electronics of the system.

NUCLIDE - A general term applicable to all isotopes of all elements. It includes both stable and radioactive forms.
Frequently, the term "isotope" is erroneously used to mean nuclide. (See ISOTOPE)

OPEN SOURCE - Radioactive material from which aliquots can be taken.

OPTICAL QUENCHING - A reduction in the scintillation intensity seen by the photomultiplier tubes due to absorption of the scintillation light either by materials present in scintillation solution or deposited on the walls of the sample container or optic (e.g., dirt). The result is fewer photons per keV of beta particle energy and usually a reduction in counting efficiency. (See CHEMICAL QUENCHING)

PARENT - A radionuclide that upon radioactive decay or disintegration yields a specific nuclide (the DAUGHTER) either directly or as a later member of a radioactive series.

PERMIT HOLDER - The individual who is permitted to purchase radioisotopes under the University of Ottawa's consolidated license. This is usually the principal investigator responsible for a radioisotope laboratory.

PHASE CONTACT - A phrase used to describe the degree of contact between two phases of heterogeneous samples. In liquid scintillation counting, better phase contact usually means higher counting efficiency.

PHOSPHOR - A luminescent substance; a material capable of emitting light when stimulated by radiation.

PHOSPHORESCENCE - See PHOTOLUMINESCENCE

PHOTOELECTRON - An electron emitted within the PMT upon exposure to photons of light. Photons are thus converted into an electrical signal.

PHOTOLUMINESCENCE - Delayed and persistent emission of single photons of light following activation by radiation such as ultraviolet.

QUANTUM - The unit quantity of energy according to the quantum theory. It is equal to the product of the frequency of the electromagnetic radiation and Planck's constant (6.6256×10^{-27} erg-sec.).

QUENCH INDICATING PARAMETER (QIP) - A value indicating the level of quenching in a sample (may be SIE, SIS, SCR, ESR or tSIE).

QUENCHING - Anything which interfers with the conversion of decay energy to electronic signal in the photomultiplier tubes. This usually results in a reduction in counting efficiency. (See also CHEMICAL QUENCHING and OPTICAL QUENCHING)

RAD - The unit of absorbed radiation dose. One rad is equal to 100 ergs/g of medium.

RADIATION - The emission or propagation of energy through matter or space by electromagnetic disturbances which display both wave-like and particle-like behavior. In this context, the "particles" are known as photons. The term radiation has been extended to include streams of fast-moving particles (alpha and beta particles, free neutrons, etc.). Nuclear radiations include alpha particles, beta particles, gamma rays and neutrons emitted from atomic nuclei during nuclear transformations.

RADIOACTIVITY - The property of an unstable nuclide of emitting radiation by spontaneous disintegration. The term is often shortened to "activity".

REGION - Similar to what is termed a "window" or "channel" in conventional liquid scintillation counters. The regions in a three region Tri-Carb system are referred to as "region A, B, or C. "

ROENTGEN EQUIVALENT MAN (REM) - The unit of dose equivalent, which is a quantity used in radiation protection. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, the distribution factor and any other necessary modifying factors. For external sources of electrons and beta particles these last three factors are assumed to be 1.0.

SAMPLE COUNTING CHANNELS RATIO (SCR) - The ratio of net counts in two selected regions or channels.

SAMPLE SELF-ABSORPTION - The absorption of radiation, emitted by radioactive atoms, by the material in which the atoms are located. In particular, the absorption of radiation within the sample being assayed. SAMPLE SELF-ABSORPTION is eliminated when the sample being assayed is dissolved in the liquid scintillation solution.

SAMPLE OXIDATION - The combustion of organic samples, in the presence of oxygen, to produce H_2O and CO_2. It is advantageous in liquid scintillation since it can be used to convert colored or insoluble samples to colorless and soluble materials.

SCATTERING - A process that changes a particle's trajectory. Scattering is caused by particle collisions with atoms, nuclei and other particles or by interactions with electric or magnetic fields. If there is no change in the total kinetic energy of the system, the scattering is called elastic. If the total kinetic energy changes due to a change in internal energy the process is called inelastic scattering.

SCHEDULED QUANTITY - Schedule quantity values are assigned to radioisotopes based upon the interplay of the physical characteristics of the radiation (type, energy, half-life) and on biological considerations (critical organs, biological half-life, body burden).

SCINTILLATION - A flash of light produced in a scintillator by an ionizing event. The scintillation is the sum of all photons produced by the decay event.

SCINTILLATION COUNTER - An instrument that detects and measures ionizing radiation by counting the light flashes (scintillations) resulting from the transfer of the energy of the radiation to scintillators.

SEALED SOURCE - Any radioactive material enclosed within equipment or encapsulated in some material. The radioactive material is not accessible.

SECONDARY SCINTILLATOR - Material in the scintillation cocktail which absorbs the emitted light of the primary scintillator and reemits it at a longer wavelength. It is added to improve the counting efficiency of the sample.

SECONDARY SOLVENT - A chemical included in the scintillation cocktail to improve sample or scintillator solubilities or to improve energy transfer.

SIGMA, PERCENT (%) - An expression of the standard deviation as a percentage. It is numerically equal to 100 times the STANDARD DEVIATION divided by the mean.

SINGLE LABEL - Only one radionuclide in a sample.

SOLUTE - A substance dissolved in a solution.

SOLVENT - Any substance that dissolves other substances.

SPECIFIC ACTIVITY - The quantity of radioactivity per unit mass, e.g., dpm/g, Ci/g.

SPECTRAL ENDPOINT - The maximum pulse height in the pulse-height distribution produced by the sample. It is of particular interest in the measurement of beta emitting radionuclides, since it corresponds to the maximum energy (E_{max}) emitted by a particular radionuclide.

SPECTRAL INDEX OF EXTERNAL STANDARD (SIE) - A number obtained from the Spectralyzer spectrum analyzer that is calculated from the spectral distribution of the external standard and is used as an index of the level of quenching in the sample.

SPECTRAL INDEX OF THE SAMPLE (SIS) - A number obtained from the Spectralyzer spectrum analyzer that is calculated from the spectral distribution of the sample, and is used as an index of the level of quenching in the sample.

SPECTRALYZER™ Spectrum Analyzer - The "spectral-analytical" section of the Packard Tri-Carb liquid scintillation counter.

SPECTRUM UNFOLDING - A technique of separating a composite dual label spectrum into its single label components.

SPILLOVER - A term used to describe the situation in dual label counting where a portion of the spectrum from one radionuclide is included in the REG ION (window) used to count the other radionuclide.
STABLE ISOTOPE - An isotope that does not undergo radioactive decay.

STANDARD DEVIATION () - A measure of the dispersion about the mean value of a series of observations. It is expressed in the same units as the mean value.

STATIC ELECTRICITY - An accumulation of electric charge on an insulated body such as a scintillation vial. In liquid scintillation counting, a discharge of static electricity may result in spurious pulses from the photomultiplier tubes.

SUMMATION - The addition of the amplitudes of the pulses received from each PMT.

TERMINATORS - The parameters used to end a sample measurement (i.e., preset time and preset count).

THREE-DIMENSIONAL SPECTRUM ANALYSIS - The analysis of the pulse energy distribution in function of energy, counts per energy, and pulse index. Allows auto-optimization of a liquid scintillation analyzer for maximum performance.

THRESHOLD LIMIT VALUE (TLV) FOR TOXICITY - The airborne concentration of a substance which produces no adverse effects which will be experienced by workers repeatedly exposed to the substance.

TOXICITY RATIO - The ratio of the equilibrium concentration of a substance to the TLV for that substance.

TRANSFORMED SPECTRAL INDEX OF THE EXTERNAL STANDARD (tSIE) - A number obtained from the Spectralyzer spectrum analyzer that is calculated from the spectral distribution of the external standard and is used as an index of quenching in the sample.

TREFOIL - The radiation symbol which is commonly recognized. It consists of a central circle and three darkened 1/6 sections of a circle.

TRITIUM - A radioactive isotope of hydrogen with two neutrons and one proton in the nucleus. It is man-made and is heavier than deuterium (heavy hydrogen). Tritium is used as a label in experiments in chemistry and biology. The nucleus of tritium is called a "triton."

UNCERTAINTY - In a nuclear decay measurement, UNCERTAINTY refers to the lack of complete knowledge of a sample's decay rate due to the random nature of the decay process and the finite length of time used to count the sample.

VECTOR QUALITATIVE ANALYSIS - The mathematical expression of the relation between the external standard quench parameter (tSIE) and the Sample Spectrum Endpoint (SEP) used in monitoring the homogeneity of the sample.

3. CNSC POLICIES

The **CNSC** requires that all licensees observe recommended guidelines and comply with all regulations. The University supports this principle and requires that:

- radioisotope users follow the **ALARA** principle described in **Section 21**;
- users do not expose other staff or the general public to any threat, real or perceived, arising from their work with radioisotopes;
- all users comply with regulations pertaining to the transportation, use and disposal of radioisotopes as outlined in this manual; and
- users exercise common sense in dealing with problems arising from their use of radioisotopes and that any questions or concerns should be addressed to **EHSS**.

4. ROLES AND RESPONSIBILITIES

It is the responsibility of each individual involved with the use of radioisotopes to ensure that all use of radioisotopes is performed in a safe manner and that regulations, policies and procedures are being observed. If you have any questions or concerns, please contact EHSS.

4.1 RADIATION SAFETY COMMITTEE

The Radiation Safety Committee acts as the University's decision maker in all areas pertaining to the use of radioactive materials. This Committee ensures that the University is in compliance with the regulations and licence conditions set out by the CNSC. Members of the Radiation Safety Committee are appointed by the Vice-Rector (Research).

The Committee has the authority to oversee the Radiation Safety Program and determines policies and procedures relevant to the use of radioisotopes at the University. It is the responsibility of the Committee to ensure that all necessary steps are taken to safeguard the health and safety of radioisotope users and non-users alike. It reviews and approves recommendations made by the Radiation Safety Officer regarding the renewal of Internal Radioisotope Permits, and has the authority to suspend internal radioisotope permits.

4.2 RADIATION SAFETY OFFICER

The Head of Radiation and Biosafety from the Environmental Health and Safety Service is the University's Radiation Safety Officer. The Radiation Safety Officer ensures day to day compliance with the requirements set out by the CNSC and the Radiation Safety Committee. This includes the development and implementation of programs which aids the safe handling of radioisotopes.

The Radiation Safety Officer manages the Radiation Safety Program at the University. The Radiation Safety Program Ottawa consists of:

- providing radiation safety training;

- implementing and monitoring dosimetry and bioassay programs;
- monitoring the purchase, use, storage and disposal of radioactive material; and
- ensuring the ALARA principle is practiced.

The Radiation Safety Officer also liaises with federal, provincial and municipal governments to ensure the University is in compliance with all applicable regulations regarding radioisotope use.

The Radiation Safety Officer derives his/her authority through the Vice-Rector (Research) and the Radiation Safety Committee.

4.3 INTERNAL RADIOISOTOPE PERMIT HOLDERS

The permit holder is responsible for ensuring that the acquisition, use, and disposal of radioactive material under their supervision complies with the appropriate set of conditions (sealed source or open source) located in Section 27. Permit holders are requested to thoroughly familiarize themselves with these conditions.
Briefly, Internal Radioisotope permit holders are required to ensure that:

- he/she is aware of any changes in University of Ottawa policies and procedures;
- radioisotopes are only used and stored in areas listed on the permit;
- only authorized users are allowed to work with radioisotopes;
- the internal radioisotope permits are up to date;
- each user is adequately trained and follows safe laboratory practice;
- the Radiation Safety manual is accessible to all users;
- contamination monitoring is performed according to the criteria of Section 17;
- inventory of radioactive materials is properly controlled, as described in Section 15;
- ensures that experimental procedures follow the ALARA principle;
- and authorized users wear dosimeters if so required.

The permit holder must provide immediate supervision to individuals who are inexperienced in the use of radioisotopes. The permit holder must ensure that individuals between 14 and 18 years of age do not use radioisotopes without direct supervision, and that no individuals under the age of 14 enter a radioisotope laboratory.

All proposed new purchases and/or disposal of instruments containing radioactive materials must be brought to the attention of the Radiation Safety Officer to ensure compliance with all regulations relating to possession and disposal of these instruments. This includes liquid scintillation counters and other instruments with internal radioactive sources, such as gas chromatograph detectors.

Any purchase of portable contamination monitors should also be brought to the attention of EHSS to assist the selection of equipment appropriate for the radioisotopes used.
The permit holder is responsible for ensuring that radioisotope laboratories are properly decommissioned prior to departure from the University of Ottawa or when the research performed no longer requires the use of radioactive materials.

4.4 USERS

It is the responsibility of the user to understand and follow the safe practices outlined in this manual. Users should inform their supervisors or alternatively, the Radiation Safety Officer of any concerns he/she may have. Users should familiarize themselves with permit conditions as outlined in Section 27.

Users of radioactive materials must understand and comply with the Radiation Safety Program (policies, procedures and regulations) at the University. In case of doubt regarding any aspect of the program, verification must be sought from EHSS.

New users should request appropriate supervision until such time as they feel comfortable with the procedures they are using.

5. RADIATION SAFETY PROGRAM

The purpose of the Radiation Safety Program is to ensure that users have the requisite knowledge and training so that they may safely perform their duties.

5.1 ROLES AND RESPONSIBILITIES

As outlined in this manual (see Section 4), there exist clearly defined roles and responsibilities for:

- radiation safety committee;
- radiation safety officer;
- permit holders; and
- users.

5.2 FACILITIES AND EQUIPMENT

Facilities and equipment should be verified by the Radiation Safety Officer to ensure compliance with all University policies and procedures, as well as CNSC regulations. This includes:

- the design of new or renovated facilities;
- protective equipment;
- monitoring equipment; and
- emergency supplies.

5.3 RADIATION SAFETY TRAINING

Radiation Safety training is the central component of the University's Radiation Safety Program. All individuals using radioactive materials are required to attend a training session. A brief description is provided in Section 10 of this manual.

5.4 PROCEDURES

Clearly defined procedures have been developed for use at the University. Permit holders and users are informed of these procedures through the University's Radiation Safety Manual and training sessions provided. The procedures outlined in this manual are specific to the University and will enable permit holders and users to comply with CNSC regulations. Procedures include:

- safety training and emergency response procedures;
- purchase/inventory control (in process of modification);
- transport packaging and receiving;
- security requirements for storage and use locations;
- contamination control; and
- dose monitoring.

6. EMERGENCY RESPONSE PROCEDURE

The most difficult part of emergency response is deciding if it is an emergency, or how important an emergency it is. Always err on the side of caution. Plan what you would do in the event of an accident **before** it occurs. If you require any additional information or guidance, please contact the permit holder or EHSS.

6.1 PLANNING

Before working with radioisotopes, plan what you would do if an accident happened. If you can think of how an accident might happen, you may be able to reduce the likelihood of such an event. For example, what would you do if an accident occurred while you were bringing a radioactive material through a public area, such as elevators or hallways?

6.2 OTHER HAZARDS

There are often other hazards associated with radioisotope work. In the case of sealed sources, these may be electrical or physical. In the case of open source work, there is often a biological or chemical hazard associated with the isotope. Develop a plan to deal with these hazards before you begin your radioisotope work.

There may be hazards specific to the isotope and its chemical form. These hazards may include volatility or reactivity as well as the type of radiation emitted. When planning for, or responding to, an emergency keep these hazards in mind. For example, unbound radioiodines pose an inhalation hazard; ^{32}P radiation is damaging to the eyes.

6.3 OPEN SOURCE

Any spill greater than 100 scheduled quantities (SQ) must immediately be reported to Protection Services. For additional assistance and clarification contact EHSS. If a spill greater than 100 SQ occurs outside of working hours, please follow the paging instructions.

Spills of more than 10 SQ should also be reported to EHSS.

Spills of less than 10 mls or spills of less than 10 SQ should be decontaminated, keeping in mind any other hazards (see Section 6.2) which may require special handling.

6.4 SEALED SOURCE

Any incident involving a sealed source must be reported to the Radiation Safety Officer. Any malfunctions of equipment containing a sealed source should also be reported to the Radiation Safety Officer.

6.5 SPILL RESPONSE PROCEDURE

For spills of more than 100 SQ, immediately inform the Environmental Health and Safety Service

1. Notify all individuals in the immediate area that a spill has occurred.
2. Increase distance from the spill. If the spill is severe, this may require evacuating the area.
3. Lock and sign door. The warning sign should include your name, as well as a location and
4. Limit access to only those individual responding to the spill.
5. If personal contamination has occurred, <u>gently</u> wash skin with a mild soap and tepid water.
6. If personal (skin) contamination has occurred, immediately contact the Environmental Health

If safe to do:

1. Contain the spill with absorbent material (paper towels).
2. Obtain any additional supplies and/or personal protective equipment (overalls, shoe coverings)
3. Push spill toward its centre. Collect all contaminated material in one appropriately labelled bag.

6.5 SPILL RESPONSE PROCEDURE

4. Decontaminate area with appropriate solutions (keep in mind biological or chemical hazards

5. If fixed contamination above twice background remains, contact the Radiation Safety Officer.

Leaving the scene after cleaning up:

1. Monitor self (especially feet, hands and lab coat) for contamination.

2. Leave lab coat behind if contaminated. Remove dosimetry badge to avoid erroneous readings.

7. RADIOISOTOPE LABORATORIES

The CNSC classifies radioisotope laboratories and regulates the physical and operational requirements of these laboratories.

7.1 CLASSIFICATION

Radioisotope laboratories at the University may be classified as basic or intermediate level, depending on the amount of radioisotope allowed.

TABLE 7.1 PERMISSIBLE QUANTITY OF RADIOACTIVITY IN SCHEDULED QUANTITIES (SQ)

LABORATORY LEVEL	OPEN BENCH	IN CONTAINMENT (FUME HOOD)
Basic	1 - 100 SQ	1 - 1 000 SQ
Intermediate	100 - 1 000 SQ	1 000 - 10 000 SQ

7.2 LABORATORY DESIGN

The Radiation Safety Officer should be contacted in the earliest stages of new laboratory design or renovation of old laboratories in order to ensure compliance with CNSC regulations and any other pertinent legislation. The CNSC requires that a Design Compliance Form be submitted for any new or renovated radioisotope laboratory. These forms are available through the Environmental Health and Safety Service. EHSS will perform an assessment of the laboratory based on the criteria outlined in R-52. These criteria are described in the following sections.

7.3 PHYSICAL REQUIREMENTS

The physical requirements of radioisotope laboratories are extensive. A basic overview is provided in this section.

7.3.1 VENTILATION

Any use of radioactive materials should be performed in a designated remote area of the laboratory. The laboratory should be at negative pressure. The airflow should be from areas of minimum likelihood of airborne radioactive contamination to areas where such contamination is more likely. In laboratories likely to generate radioactive aerosols or fumes, all air should be vented through a fume hood. There are extensive requirements for fume hood certification.

7.3.2 FINISHING AND FIXTURES

Finishing and fixtures should be chemical resistant, smooth, washable, with all joints sealed. Cleanliness is paramount.

7.3.3 PLUMBING

Sinks designated for use with radioactive materials should be clearly labelled. Sink traps should be accessible. Back-flow prevention devices should be used on vacuum or cooling lines.

7.3.4 STORAGE

Radiation levels outside storage areas should not exceed 2.5 uSv/hr.

7.3.5 SECURITY

Radioisotope laboratories should have a solid lock on the door.

7.3.6 MISCELLANEOUS

Coat hooks should be provided close to the exit of the lab. No food or drink is permitted in the lab. Radioactive materials are not to be located near desks. Intermediate level labs should install an appropriate radiation monitoring device.

7.3.7 INCIDENTAL RADIATION

Radioisotope laboratories should be designed to minimize incidental radiation. Storage locations should be shielded (if necessary) on all sides. radiation can pose a hazard to individuals in rooms abutting the radioisotope laboratory.

The possibility of incidental exposure to others should be taken into account when designing work areas. Avoid using centre benches when working with radioisotopes, especially those which require shielding. When using isotopes which emit gamma radiation, try to work near an outside wall.

8. PERMITS

Each radioisotope laboratory is issued a permit to use radioisotopes under the University of Ottawa's consolidated radioisotope license. The Internal Radioisotope Use Permit must be clearly posted in each laboratory. The consolidated license makes the University responsible for ensuring compliance with CNSC regulations. The CNSC could suspend the University's license due to non-compliance of a single permit holder. For information on how to obtain a radioisotope permit, please contact EHSS.
Principal Investigators may only purchase radioisotopes once they have received and posted an Internal Radioisotope Use Permit. Please contact the Radiation Safety Officer to request a Sealed Source Internal Radioisotope Permit. Principal Investigators who wish to use open source radioactive materials must complete the Open Source Radioisotope Permit Application form (see Section 28) and return it to the Radiation Safety Officer. All applications are reviewed by the Radiation Safety Officer and the Radiation Safety Committee. Once the application is approved, the Radiation Safety Committee will issue a permit for your laboratory.

Permit holders must notify the Radiation Safety Officer of any modifications to an existing permit, such as new users or the addition of a different isotope.

TABLE 8.1 FORMS REQUIRED				
SOURCES	**NEW LAB**	**NEW PERMIT**	**NEW ISOTOPE**	**NEW USER**
Sealed Source	Laboratory Data Sheet	Contact RSO	Contact RSO	Radioisotope User Registration Form (Section 28), if required
Open Source	Laboratory Data Sheet	Open Source Radioisotope Permit Application (Section 28)	Contact RSO	Radioisotope User Registration Form (Section 28)

All sealed sources require a permit, including those incorporated in a device. Contact the Radiation Safety Officer for an application for a sealed source permit. If you wish to acquire an additional sealed source, your permit must be updated **before** you receive the source.

9. SIGNAGE REQUIREMENTS

A radioisotope use sign must be posted at the entrance to any room which contains radioactive material. Emergency contacts with up to date phone numbers should be clearly identified.

A clearly visible and legible sign must be posted on or near any device containing a radioactive substance, including liquid scintillation counters and freezers.

The Internal Radioisotope Permit must be prominently displayed.

CNSC has issued Radioisotope Safety Guidelines for radioisotope laboratories (INFO-0142-n/Rev. 2), which must be posted in each area where radioisotopes will be used or stored. Users should refresh their memory by re-reading these guidelines at regular frequencies.

10. TRAINING

Sealed source users receive specific instruction from the permit holder. Open source users are required to participate in the Radiation Safety training session. The training is offered at the beginning of each semester, at both Main campus and Guindon Hall. Please contact EHSS for details regarding scheduling and registration.

10.1 NEW USERS

Before working with any radioisotope new users must:

- complete a Radioisotope User Registration Form (see Section 28);
- attend the Radiation Safety training session provided by EHSS; and
- receive any necessary dosimeters from the person responsible for the department.

10.2 PERMIT HOLDERS

Permit holders must ensure that:

- all users have attended the training session and received any required dosimeters;
- all users are aware of any pertinent information regarding isotope, chemical form and laboratory specific procedures; and
- they are fully aware of any changes in policies and procedures of the University.

11. DOSIMETRY

New users may only use radioisotopes after obtaining any required dosimeters. The type of dosimeter required is determined by the use limit on the permit and is clearly stated for each user listed on the permit. The dosimeters are changed on a regular basis (i.e. quarterly). Please contact EHSS to obtain dosimeters.

Dosimeters are assigned to a single individual and should only be worn by that individual when he/she is in the radioisotope laboratory. A national dosimetry registry is maintained by Health Canada. If you should require your dose records, please contact them directly.

CNSC must be informed within 24 hours if any individual exceeds the annual dose limit or **may** exceed the annual dose limit as the result of an incident. Dosimeters **must not** be worn when undergoing medical procedures involving radiation, as this may cause dosimeters to register an excessive dose.

Any individual who has received an exposure greater than 1/10 of the annual limit specified in Table 11.1 will be contacted by the Radiation Safety Officer. Unless you are contacted by the Radiation Safety Officer, you may assume that your doses are negligible.

The dose received is measured in Sieverts (Sv). This is the absorbed dose multiplied by a 'quality factor' indicative of the biological effect which the radiation may have.

11.1 REGULATIONS REGARDING PERMITTED DOSE

Under Atomic Energy Control Regulations all employees at the University are classified as members of the general public.

Pregnant workers must notify the Radiation Safety Officer (see Section 23). A pregnancy schedule for dosimetry monitoring is available.

TABLE 11.1 MAXIMUM PERMISSIBLE DOSES LEVELS

ORGAN	MAXIMUM ANNUAL DOSE (mSv)	MAXIMUM ANNUAL DOSE (rems)
Whole body, gonads, bone marrow	5 mSv	0.5 rems
Skin, thyroid, bone	30 mSv	3 rems
Hands, feet and forearms	75 mSv	7.5 rems

11.2 CRITERIA FOR DOSIMETRY

Individuals working with radioisotopes may be required to wear a dosimeter depending on the type and energy of the radioactive emission as well as the amount of isotope used. Extremity (wrist or finger badges) are not required for less than 1 mCi of radioisotope.

11.3 THERMOLUMINESCENT DOSIMETERS (TLD)

TLD badges are extremely sensitive to ultraviolet light and will give false readings if they are exposed to sunlight or other UV sources, such as transilluminators or germicidal lamps.

TLD badges consist of two LiF chips. One chip is covered by a piece of aluminium, the other by mylar tape. The two chips are processed in order to determine exposure levels. The chip which is covered by aluminium represents the whole body dose, while the tape covered chip represents the dose received by the skin. If the foil on your TLD badge is damaged, you should immediately contact EHSS.

Individuals responsible for distributing TLD badges will:

- ensure that dust and dirt are not deposited on the plaques;
- inform EHSS of any chipped or damaged dosimeters; and
- ensure that the foil on the exterior surface of the holders is not damaged.

Extremity dosimeters are generally referred to as wrist or finger dosimeters. These function in the same way as TLD badges, but measure the dose received by the arms and hands of the user. They are used when working with significant amounts of high energy beta emitters such as ^{32}P.

TLDs cannot detect radiation exposure to ^{3}H, ^{14}C, ^{35}S or ^{45}Ca.

11.4 THYROID BIOASSAY

Unbound ^{125}I or ^{131}I presents special risks of accumulation in the thyroid. Individuals who, within a three month period, use more than 135 uCi (5MBq) of ^{125}I or ^{131}I on the open bench or more than 1.35 mCi (50MBq) of ^{125}I or ^{131}I in a fume hood must participate in the thyroid bioassay program. Any other individual who is deemed by the Radiation Safety Officer to be likely to receive a significant intake of unbound radioiodine is also required to take part in the program. The Radiation Safety Officer must be contacted one week prior to each iodination in order to schedule a pre and post-iodination thyroid monitoring session.

12. ORDERING

An Internal Radioisotope Permit is required in order to purchase radioactive material.

All radioisotope purchases must be approved by EHSS and made through a purchasing agent. Each purchasing agent is provided with a copy of all internal radioisotope permits for individuals under his/her jurisdiction. Purchasing agents are authorized to refuse to order any radioactive material if the individual does not have a permit or if the isotope or activity does not correspond to the permit conditions.

In order to minimize any delays, purchasing agents are immediately notified of any modifications to the permits.

13. TRANSPORTING

Transportation of radioactive materials must be done in such a manner as to minimize exposure of both users and the general public.

13.1 OUTSIDE THE UNIVERSITY

Transfer of radioactive materials outside the University requires pre-authorization from the Radiation Safety Officer. This is to ensure that the proposed recipient is authorized to receive such a shipment. The Radiation Safety Officer will also ensure that all aspects of the transfer procedure comply with the *Transportation of Dangerous Goods* (TDG) regulations. The use of personal automobiles to transport radioactive materials on public roadways is specifically prohibited.

13.2 WITHIN THE UNIVERSITY

Radioactive materials may only be transferred within the University among holders of internal radioisotope permits located within the same campus. Transferring radioactive materials between campuses requires compliance with the TDG regulations, and must follow the same procedure as transfer outside of the University (see Section 13.1). Permit holders must ensure that any recipient located on the same campus has an Internal Radioisotope Permit, and that the quantity and activity are within permit limitations. The amount and activity transferred should be listed on the inventory log sheet in both laboratories. The recipient permit holder becomes responsible for performing the appropriate contamination monitoring.

13.3 TRANSPORTING OPEN SOURCE MATERIAL

When transporting open source radioactive materials, including waste, within a single campus users must:

- use the elevators, not stairwells. This is to reduce the possibility of trips or falls which may lead to spills;
- use an appropriate shielding box, with four sides, a lid and a bottom, in either lead or plexiglass, depending on the isotope for high energy and emitters;
- carry the box on a leak proof tray;
- have a plan to deal with accidental spills;
- minimize exposure of other workers and the general public - do not shield yourself and bump into others;
- ensure that caps and lids are tight;
- wear appropriate protective equipment, such as gloves - this may require an assistant to open doors; and
- clean up and decontaminate any spill which may occur.

13.4 TRANSPORTING A SEALED SOURCE

When transporting a sealed source, the user must ensure that adequate shielding is maintained. The Radiation Safety Officer must be notified of any change in location of a sealed source, either temporary or permanent, in order to update the permit.

13.4.1 ENCLOSED WITHIN EQUIPMENT

The Radiation Safety Officer must be notified before moving sealed sources enclosed within equipment, including liquid scintillation counters. This notification is required in order to update the location listed on the permit. Any incident or possible damage to the equipment occurring during transport must be communicated immediately to the Radiation Safety Officer.

13.4.2 ENCAPSULATED SEALED SOURCE

Encapsulated sealed sources must be transported within a properly shielded container, in accordance with departmental procedure. The level of radiation from a properly shielded source should not exceed 2.5 μSv/hr. Planning is necessary to reduce the risk of an accident occurring during the transfer. Any incident which occurs during transfer should be reported to the Radiation Safety Officer.

14. RECEIVING RADIOACTIVE PACKAGES

CNSC has developed a standard procedure for receiving radioactive packages (INFO-0426). This procedure should be prominently displayed in areas where radioactive packages may be received. Individuals who may receive radioactive packages should be familiar with this procedure. In addition, individuals signing for radioactive packages should be TDG trained.

Radioactive packages which have suffered visible damage must be reported to the Radiation Safety Officer. Staff and students who may receive radioactive packages should be trained regarding the:

- nature of radiation;
- risk of exposure;

- regulations and regulatory bodies;
- labelling and packaging requirements;
- external inspection procedure; and
- monitoring requirements.

Radioactive packages are categorized as outlined in Table 14.0, according to the transport index (TI) of the package. The TI is one-tenth the maximum radiation level one metre from the package. Since category II and III packages are emitting radiation, it is important to minimize exposure. Place the package on a cart in order to reduce personal exposure. Reduce exposure of co-workers or the general public by transporting the package through low traffic areas and offering verbal warnings if appropriate. Reduce time of exposure by immediately placing the radioactive source in secure storage.

TABLE 14.0 CLASSIFICATION OF RADIOACTIVE PACKAGES

CATEGORY	RADIATION AT PACKAGE SURFACE	RADIATION 1m FROM SURFACE	TRANSPORT INDEX	EXAMPLE
Category I	5 uSv/hr 0.5 mRem/hr	-	-	^{14}C
Category II	500 uSv/hr 50 mRem/hr	10 uSv/hr 1 mRem/hr	1	^{32}P
Category III	2 mSv/hr 0.2 Rem/hr	100 uSv/hr 10 mRem/hr	10	^{22}Na

14.1 OPEN SOURCE

Recipients of a package containing radioactive material must follow CNSC procedure when receiving such a package. When you receive a package of radioactive material:

- use a portable contamination monitor (Geiger counter) to verify that radiation levels on the outside of the package do not exceed allowable limits; and
- monitor the internal packaging for contamination.

The Radiation Safety Officer is to be notified if any problem arises during receiving, delivery or if the shipping container is damaged.

Once a shipment has been received at Receiving the following information should be logged:

- date of arrival;
- purchase order number;
- department to receive shipment;
- number of pieces;
- supplier name;
- carrier name; and
- waybill number.

The permit holder is then contacted for in-house pick up. If this is not possible, the parcel must be stored in an area which is clearly labelled and access restricted.

14.2 OPEN SOURCES TRANSFERRED WITHIN THE UNIVERSITY

Any radioactive material may only be transferred within the University among holders of internal radioisotope permits located at the same campus. Note that recipient permit holders must have the radioisotope listed on their permit; the quantity and activity permitted must also allow such a transfer. This transfer must be documented in the inventory log (see Section 15.1).

14.3 SEALED SOURCE

The transfer of sealed sources is strictly regulated, including the transfer of sealed sources enclosed within equipment. If you wish to receive a sealed source, please contact the Radiation Safety Officer for instructions regarding proper procedures. These procedures will be determined on an individual basis.

15. INVENTORY

CNSC requires strict inventory control of radioactive material.

A University-wide inventory is maintained by EHSS. Any acquisition or disposal of radioactive materials must be reported to the Radiation Safety Officer in order to ensure that this inventory is up to date.

15.1 OPEN SOURCE

One inventory log sheet (see Section 28) must be kept for each open source item purchased or received. The log sheet header should be completed as soon as the item is received. Log sheets must be kept on file for three (3) years following disposal of the item. Log sheets will be reviewed during inspections conducted by both EHSS and CNSC.

Each withdrawal of radioisotope must be specified on the log sheet. The disposal profile for each withdrawal must also be described. When completing a disposal profile after a substantial decay period, please **account for this decay** (see Sections 16 and 22).

When the item is completely disposed, please forward the completed inventory log sheet to EHSS.

15.2 SEALED SOURCE

Sealed source inventories are listed on the Internal Radioisotope Use Permit. Any change to this inventory must be reported to the Radiation Safety Officer **prior** to the acquisition or disposal of a sealed source, including those enclosed within equipment.

16. DISPOSAL

Every precaution must be taken to ensure the safety of individuals handling radioactive waste after it leaves the laboratory. Radioactive waste often includes a chemical or biological hazard. It is necessary to consider these hazards when disposing of radioactive waste.

16.1 OPEN SOURCE

Open source material may be disposed via the following routes:

- **decay/landfill:** waste held for decay until it is below 1 SQ/kg (see Section 16.1.1), then disposed to regular garbage
- **drain:** aqueous waste disposed to the municipal sewage system (see Section 16.1.2)
- **LSC:** liquid scintillation cocktail waste (see Section 16.1.3)
- **carcass:** animal carcasses contaminated with radioisotope (see Section 16.1.4)

The disposal profile for each aliquot withdrawn must be recorded on the Inventory of Use and Disposition Form, as outlined in Section 15.1.

Any toxic or organic radioactive waste (excluding LSC) will require special disposal depending on the identity of the specific isotope and its concentration in the waste. A specific disposal procedure must be developed in consultation with the Radiation Safety Officer (see Section 16.1.2.2).

In exceptional circumstances it may be necessary to dispose of radioisotope through external disposal companies where the methods outlined in this section are unable to permit safe and legal disposal. If you are planning an experiment which you believe may require this type of disposal, please contact the Environmental Health and Safety Service for guidance.

16.1.1 SOLIDS TO DECAY/ LANDFILL

Radioisotope contaminated solids may be disposed in the regular waste if the concentration of radioisotope is less than **one scheduled quantity per kilogram (1 SQ/kg)**, **uniformly** distributed, see Table 25.1. Solid waste with an activity greater than this should be held for decay, if the half life is less than 90 days, see Table 16.1.1 A. Solid waste should not include toxic materials. Infectious materials must be decontaminated prior to disposal. Liquids associated with solid materials, such as assay tube contents, must be decanted or removed by aspiration.
Accurate records of the activity of the waste generated must be kept in order to determine the period of time necessary for decay .

A University of Ottawa Radioactive Solid Waste Log (see Section 28) taped to the surface of the waste can simplifies record keeping. The information required is:

- user's name;
- estimated total activity of each disposal ;
- time period over which waste was collected; and
- final weight of the filled container, minus the empty container weight.

Wastes containing isotopes with half-lives greater than 90 days are not suitable for using decay as a means of waste management due to long storage times required.

The time required for decay is determined as follows:

$$t = \frac{\ln A/A_0}{- A}$$

where is the isotope's decay constant
is the activity after decay in SQ
A_0 is the original activity in SQ
t is the time required for decay

The decay constants for selected isotopes are listed in Table 16.1.1 A.

TABLE 16.1.1 A) HALF-LIVES AND DECAY CONSTANTS OF SELECTED RADIOISOTOPES		
RADIOISOTOPE	**HALF-LIFE**	**DECAY CONSTANT**
^{3}H *	12.3 years	0.0563 / year
^{14}C *	5730 years	0.0001 / year
^{22}Na *	2.60 years	0.267 / year
^{32}P	14.3 days	0.0485 / day
^{33}P	25.4 days	0.028 / day
^{35}S	87.4 days	0.008 / day
^{36}Cl *	300 000 years	effectively 0
^{45}Ca *	165 days	0.004 / day

TABLE 16.1.1 A) HALF-LIVES AND DECAY CONSTANTS OF SELECTED RADIOISOTOPES		
RADIOISOTOPE	HALF-LIFE	DECAY CONSTANT
^{51}Cr	27.7 days	0.025 / day
^{54}Mn *	312.7 days	0.002 / day
^{86}Rb	18.66 days	0.0371 / day
^{125}I	60.14 days	0.012 / day

∗ Due to their long half-lives, decay of these isotopes are impractical from a waste management perspective.

TABLE 16.1.1 B) SOLID WASTE DECAY PROCEDURE	
1	Deface all radioactive labelling on any items to be disposed. Remove both symbols and written warnings.
2	Decontamination should occur whenever possible. Rinse with water to reduce the activity associated with solid wastes.
3	Store each isotope in a separate container.
4	Sharp objects such as needles, Pasteur pipets and broken glass must be placed into a sharps container prior to disposal. Affix a "For Radioactive Decay" label to the container. Allow the necessary time for decay, then remove the label and dispose as per regular sharps disposal procedure.
5	All non-sharp waste must be held for decay in 20 L plastic pails.
6	All decay waste pails must have a plastic inner liner. Under no circumstances are solids to be placed in unlined waste pails. Biohazards bags may only be used if the waste also contains biohazardous components.
7	A University of Ottawa "For Radioactive Decay" label should be affixed to the exterior surface of the decay can. Labels are available from stores at both the Faculty of Science and the Faculty of Medicine.
8	When the pail is full, seal it with tape and bring it to the central decay facility for your building during hours of accessibility (if you don't know where this facility is located, please contact the Environmental Health and Safety Service).
9	Once the contents have decayed, it is the responsibility of the permit holder to retrieve the pail from the decay facility. The bag can then be removed from the can and disposed as regular waste, unless other waste components prohibit disposal to landfill (i.e. chemical).

16.1.2 LIQUIDS

Radioactive liquid waste can be either aqueous or organic. Aqueous waste includes biological buffers and other water based liquids. Organic waste is any waste which contains organic solvents such as phenol or chloroform.

16.1.2.1 AQUEOUS LIQUID WASTE

Aqueous liquid waste may be disposed of in the municipal sewer system. Each laboratory shall designate one sink to be used for radioactive work and disposal. This sink must be appropriately labelled with radioactive warning tape. This sink must be included in the regular monitoring program (see Section 17.1).

Solutions containing **infectious** agents must be disinfected by chemical or physical means prior to disposal.

Aqueous solutions containing **toxic** material will have the disposal procedure decided upon based on the type of toxic material, its concentration and the radionuclide involved. The Radiation Safety Officer should be contacted in order to determine an appropriate disposal procedure.

Unbound **Iodine-125** with an activity greater than 100 uCi. This refers to either unused radioiodine or the resultant free iodine peak after separation from the bound peak in radioiodination procedures. Since unbound iodine in significant quantities presents an inhalation hazard, this material requires treatment prior to disposal. Using chloramine T as per your standard labelling protocol, add an excess protein source such as bovine serum albumin. This will result in covalent binding of the remaining iodine to the protein, thus removing the inhalation hazard. In this state it may now be disposed to the sewer.

TABLE 16.1.2.1 PROCEDURE FOR DISPOSAL OF RADIOACTIVE AQUEOUS LIQUID WASTE	
1	Drains suspected of having plumbing problems should not be used. A periodic check beneath the sink is advised to ensure that no leakage remains undetected.
2	Liquids should be poured directly into the drain in order to minimize contact with the sink surfaces. Sink surfaces should be included in the weekly contamination monitoring program.
3	Water should run for two (2) minutes immediately **after** disposal.

16.1.2.2 ORGANIC LIQUID WASTE

The identity of the specific isotope and the concentration of the organic component must be known and reported to the Radiation Safety Officer. The disposal route will be determined based on the concentration of the radioisotope and whether the half-life is short enough that it may be held for decay and disposed as organic liquid waste. Follow all safety precautions required for handling organic chemicals.

16.1.3 LIQUID SCINTILLATION COCKTAIL WASTE

Liquid Scintillation Cocktail (LSC) is disposed as low-level radioactive waste. There is also a significant chemical hazard associated with LSC. Municipal and provincial governments do not accept the 'biodegradable' designation for LSC as acceptable for disposal to the sanitary sewer. It is important that neither solids nor any other organic solvents be included with LSC. Dispose of LSC vials directly into twenty litre plastic pails, do not attempt to decant the fluid. Do not attempt to combine the fluid of different vials.

LSC is used in conjunction with:

- open sources, for wipe tests and assays
- sealed sources, for leak testing

TABLE 16.1.3 PROCEDURE FOR DISPOSING OF LSC	
1	Place two liners inside a 20 litre pail and place two trefoils on the outside of the pail. Identify the pail as "Liquid Scintillation Waste".
2	Ensure that the vials are tightly closed.
3	Fill out Liquid Scintillation Waste Log sheet (see Section 28) including the user name, date, activity, isotope, and number of vials. Logs should be updated as material is added to the waste container.
4	Do not over fill the pail, the lid must close properly.
5	When the pail is full or every three (3) months (which ever comes first), contact the Environmental Health and Safety Service (562-5892) to arrange for transfer of the waste pail to the disposal room.

16.1.4 CARCASS

EHSS must be informed **prior** to the disposal of animal carcasses contaminated with radioactive

materials. Disposal shall be as directed by the Animal Care Service, in consultation with the Radiation Safety Officer.
In some cases, animal faeces, urine or bedding must be disposed as radioactive material. The Radiation Safety Officer will inform you of any required precautions after reviewing your protocol.

16.2 DISPOSING OF SEALED SOURCES
Please contact the Radiation Safety Officer for instructions regarding the disposal of a sealed source. EHSS can make arrangements for recycling sealed sources. Sealed source permit holders may use liquid scintillation cocktail for leak testing. Disposal of this waste should follow the procedure outlined in Section 16.1.3.

17. MONITORING
Contamination monitoring must be performed in any laboratory which has a permit to use radioisotopes. Results must be supplied upon request to inspectors. Results should include the date of measurement, the make and model of the instrument used for measuring, locations monitored, and background measurement.

17.1 MONITORING OPEN SOURCES

Monitoring must be performed weekly for procedures using less than 1000 SQ. When more than 1000 SQ are used, immediate monitoring is required. When the isotopes are not used during the week, it is acceptable to write "not used" in the log. All instructions on the Record of Contamination Monitoring Monthly Log (see Section 28) must be followed. The contamination monitoring results must be kept on file for three (3) years.

17.1.1 ESTABLISHING A CONTAMINATION MONITORING PROGRAM

- A plan of the laboratory must be prepared which identifies all locations to be monitored. Each location should correspond to a number in the log entry. Locations for monitoring should include working surfaces, storage areas and non-working surfaces such as door handles, sinks and autoclaves.
- The type of counter and the counting time should be indicated for each isotope. If the same counter and window is used to detect all the isotopes in use, only one series of wipe tests need be performed.
- A background sample must be included in the program.
- Monitoring must be performed at least weekly when the isotope is in use, preferably on a specified day by a designated individual.
- Record the results on the Record of Contamination Monitoring Form (see Section 28).

17.1.2 MONITORING WITH A PORTABLE COUNTER

Portable monitors should be calibrated on a regular basis. Weak energy emitting isotopes such as ^{3}H cannot be detected by a portable counter, therefore a wipe test must be performed. A portable monitor (geiger) may be used when the efficiency of detection for the isotope is at least 20 % (see Section 22.2). Manufacturers will provide detailed information regarding a monitor's counting efficiency for specific isotopes.

17.1.3 MONITORING BY WIPE TESTS

Remember that wipe tests only measure removable contamination. Each individual area must be wiped separately.

17.1.4 PROCEDURE FOR WIPE TESTING	
1	Use a filter paper of approximately 1 cm^2, lightly moistened with water or alcohol. Prepare a background sample in the same fashion but do not perform step 2.
2	Wipe a representative area (100 cm^2) in each of the designated areas.
3	Place each wipe in a vial (liquid scintillation) or gamma tube labelled to correspond with the sample location.
4	Allow the filter paper to dry and prepare the sample as per standard protocol.
5	Count the sample using the appropriate detector.
6	Record or append the results in the log.

17.2 MONITORING SEALED SOURCES

The purpose of leak testing is to ensure the structural integrity of the material encapsulating a sealed source. Leak testing must be performed regularly, in accordance with permit requirements. These requirements are clearly stated on the internal radioisotope use permit which is posted in the laboratory. Leak testing protocols are specific to each source and must be approved by CNSC. Leak tests generally consist of a wipe test (see section 17.2.1). Results must be kept on file for three years.

If 200 Bq (0.005 uCi) (12,000 dpm) or greater is detected the Radiation Safety Officer must be contacted immediately.

17.2.1 LEAK TEST PROCEDURE	
SOURCE LEAK TESTING REQUIREMENTS: Sealed source wipe leak testing consists of two parts, wiping the source and measuring the wipe sample.	
1	Wipe sampling procedure documentation: a) a general description of the method of wipe sampling; b) a list of all sealed sources to be leak tested, and their locations; c) a step by step procedure of the method for wipe sampling each type of sealed source and each type of sealed source containment; d) a description of the types of wipe sample containers; e) an example of a completed leak test sampling certificate.
2	Sampling shall only be performed by a person who: a) knows the requirements of this guide; b) knows the type and activity of the sealed source and the sealed source containment; c) can recognize and minimize the potential contamination and radiation hazards.
3	Requirements for sampling records.

17.2.1 LEAK TEST PROCEDURE	
SOURCE LEAK TESTING REQUIREMENTS: Sealed source wipe leak testing consists of two parts, wiping the source and measuring the wipe sample.	
4	Measuring procedure documentation: a) a general description of the method of measuring; b) a step by step procedure for measuring wipe samples; c) an example of a completed leak test measuring certificate.
5	Requirements for measuring: a) knows the requirements of this guide; b) is familiar with the operation of the measuring equipment; c) can recognize and minimize the potential radiation and contamination hazards associated with the wipe sample; d) has available and follows the procedure detailed in section 4; and e) has available sufficient blank leak test measuring certificates.
6	Requirements for record completion.
7	Frequency.

17.2.2 RECORD KEEPING REQUIREMENTS

The licensee shall maintain for three (3) years:

a) a sealed source inventory;
b) all leak test sampling certificates, and
c) leak test measuring certificates.

17.3 CONTAMINATION AND DECONTAMINATION

Contamination is any activity found to be greater than twice the background rate. Areas of contamination must be investigated, decontaminated, and monitored again. If decontamination is not possible, record this as **fixed contamination** and notify EHSS.

CNSC defines contamination as 5 Bq/cm^2 of beta and gamma radiation averaged over an area not exceeding 100 cm^2. To determine if contamination exists:

$$Bq/cm^2 = \frac{Cpm}{(CE) \times A}$$

Where Cpm = counts per minute
CE = counting efficiency
A = area

For a counter which is 20% efficient (see Section 22), this means 100 cpm. In practice, the University defines contamination as twice background.

17.4 PROCEDURE FOR DECONTAMINATION	
1	Moisten a paper towel with an appropriate detergent.
2	Wipe area.
3	Repeat until area is no longer contaminated.
4	If fixed contamination remains, contact the Radiation Safety Officer.

18. INSPECTIONS

Inspections are performed regularly by both CNSC and EHSS. Any areas of concern must be promptly addressed by the permit holder.

Inspections serve to verify compliance with CNSC regulations and license conditions, check that the permitting system is working well, and to identify situations which could be improved.

18.1 CNSC

CNSC performs regular inspections. CNSC issues orders to notify the University of compliance deficiencies. These deficiencies must be addressed, or the license to use radioisotopes may be suspended. The CNSC directive may include the decommissioning of non-compliant laboratories. CNSC inspections verify compliance with all regulations as well as the general conditions outlined in Section 27.

18.2 UNIVERSITY OF OTTAWA

The Radiation Inspector performs regular inspections of permit holders. Inspections are performed in order to ensure:

- compliance with all pertinent regulations and the conditions of the consolidated license, and
- that all radioisotope users are properly trained and knowledgeable of the policies and procedures in force at the University.

19. DECOMMISSIONING A RADIOISOTOPE LABORATORY

Before leaving the University, all permit holders must decommission their radioisotope laboratory. The inventory information and monitoring results must be forwarded to EHSS.

19.1 INVENTORY

The permit holder must indicate that **all** radioisotopes in the laboratory has been depleted by:

- following the disposal procedures outlined in this manual;
- not acquiring any new radioactive materials, and/or
- transferring any remaining inventory to another permit holder within the University.

Transfer of radioisotope to another permit holder must follow the procedures outlined in Section 14. The Radiation Safety Officer must receive a written record of any transfer stating the recipient, the radioisotope and its activity. A copy must be kept by both the permit holder conducting the decommissioning and the recipient permit holder.

19. 2 CONTAMINATION MONITORING

Monitoring should include all locations where radioisotopes were used or stored, as well as other random locations or locations where accidental contamination may have occurred. These wipes should be counted for 10 minutes, and a blank (background) sample must be included. Decontamination (see Section 17.1.4) must be conducted if any contamination is detected. Successful decontamination must be confirmed by another wipe test.
The actual printouts from a scintillation or gamma counter (appropriately labelled) must be forwarded to

EHSS.

19. 3 REMOVAL OF RADIOACTIVE SIGNAGE

All radioactive symbols and warnings must be removed from all equipment, benches, refrigerators, doors, etc.

20. THE NATURE AND EFFECTS OF RADIATION

Radiation can be classified as either non-ionizing or ionizing radiation. Non-ionizing radiation includes heat, lasers and other forms of radiation which cannot affect the charge of an atom. Ionizing radiation can change the charge of an atom. This manual is devoted entirely to ionizing radiation, but uses the term radiation for the sake of brevity.

Much of the information contained in this section was modified from the University of British Columbia Radiation Safety Manual.

20.1. HISTORICAL REVIEW

At the time of the formation of this planet, much of the constituent matter was radioactive. Over the millennia, this activity decayed until only those radioisotopes with extremely long half-lives (e.g. Uranium-238; 4.47×10^9 years) and their decay products are found in the earth. The radioactive material that is used in most scientific research and medicine is generated in particle accelerators or nuclear reactors.
We are continually exposed to atomic radiations of planetary origin and are bombarded with different types of radiations emanating from the sun and stars and galaxies. As cosmic radiation enters our atmosphere, it generates radioactive atoms, such as Carbon-14, that become incorporated into our water and food supplies. Life on earth has evolved in this inescapable bath of naturally occurring radioactivity and all living organisms, including humans, assimilate this material into their basic chemical make-up.

Although ionizing radiation has been present from the beginning of time, it was not until the year 1895 that Wilhelm C. Roentgen discovered x-rays. Interest in this "new ray" was immediate and intense. Within a few months the first cases of injury due to radiation overexposure (erythema, skin burns, aplastic anaemia) were seen by physicians, who knew neither about the origin of these injuries nor of any appropriate therapeutic response.

Within one year of Roentgen's discovery of x-rays, Henri Becquerel discovered that uranium salts emitted radiation capable of exposing photographic films. In 1898, the element, Polonium was isolated from tons of ore by Marie and Pierre Curie. Intensive research then followed, resulting in the isolation of the radioactive element radium and the discovery of, and subsequent investigation of alpha particles. It is reported that the labs in which this research was performed were highly contaminated with radium, as quantities of up to a gram of the material were used in some instances. Some of the initial health effects encountered were skin burns, deformed fingers and cancer. Another group of occupationally exposed workers were women employed in the 1920s as watch dial painters. In the process of their work, they ingested small amounts of radium and many later died of different types of radiation induced cancers.

The first organized step toward radiation protection standards was made in 1915 at the first meeting of the British Roentgen Society, at which a resolution was passed that "...this Society considers it a matter of greatest importance that the personal safety of the operators conducting the roentgen-ray examinations should be secured by the universal adoption of stringent rules...". In 1928, at the Second International Congress of Radiology, an International Committee on X-Ray and Radium Protection (now known as the International Commission on Radiological Protection - ICRP) was constituted. Early efforts of the ICRP were concerned with establishing radiation units and making some interim protection recommendations. Today the ICRP conducts in-depth studies of the many facets of radiation protection, makes recommendations and issues reports which form the basis for legislation worldwide.

20.2 BOHR'S MODEL OF THE ATOM

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

The nucleus is the central core of the atom and is composed of two types of particles; positively-charged protons and uncharged neutrons. The weight of each neutron and proton is approximately one atomic mass unit (amu) and is equal to 1/16 of an oxygen atom or 1.67×10^{-24} grams.

Electrons revolve around the nucleus at discrete and well defined orbital distances. Each electron carries a negative electrical charge and is 1/1836 the weight of a proton. There are 104 different naturally occurring elements, each of which is characterized by two related terms:

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

Atomic Formula = $^{A}_{Z}X$

Given that the number of protons, and hence the atomic number, defines a specific type of atom, the number of neutrons may change without changing the chemical characteristics of that atom. Isotopes are defined as having equal numbers of protons but different numbers of neutrons (see Figure 20.2). Isotopes of an element have the same atomic number (Z), but a different mass number (A). The ratio of protons to neutrons may cause the atom to be unstable. Radioisotopes are unstable isotopes which spontaneously decay into new, stable isotopes by emitting ionizing radiation. There are three or more isotopes for every element, at least one of which is radioactive. Some elements, such as Plutonium, have no stable isotopes.

$^{1}_{1}H$	$^{2}_{1}H$	$^{3}_{1}H$
Protium (stable)	Deuterium (stable)	Tritium (radioactive)

Figure 20.2 Isotopes of Hydrogen

This decay process may consist of multiple steps and, depending on the proton to neutron ratio and mass-energy relationships, may involve:

- the emission of charged particles (and emissions);
- electron capture; and
- the emission of excitation energy (or x-rays)

When a radioisotope decays, it produces radiation and a new atom. This may be important in biological systems, as the final product may have an effect on the system. For example ^{226}Ra decays into ^{222}Rn (Radon gas), which is volatile and poisonous. The time required for half the radioisotope to decay is called the physical half-life ($t_{1/2}$).

The energy emitted by decaying radioisotopes can be absorbed by nearby objects. If it is absorbed by a living being, it may have biological effects.

20.3 DECAY SCHEMES

The atomic decay and its by-products may be graphically represented in a 'decay scheme'. The horizontal line at the top represents the parent radioisotope, and lower horizontal lines represent daughter products. The name, atomic number and half-life of each radioisotope are placed on their respective lines. Negatively charged decay products are represented by a diagonal line towards the lower right, while positively charged particles are towards the lower left. The amount of this type of radiation (as a percentage) and the maximum kinetic energy of the radiation (in Mev) are placed near the line representing that radiation. -radiation is represented by wavy lines. Some decay schemes can be quite complex.

Figure 20.3 Decay Schemes

20.4 TYPES OF RADIATION

The decay of unstable isotopes can occur in a variety of fashions. Each form of radiation has physical characteristics and a specific amount of energy. The physical and energetic qualities of a radiation determine its effect. The characteristics of the different forms of radiation are outlined in Table 20.4.

TABLE 20.4 CHARACTERISTICS OF IONIZING RADIATION

TYPE	ORIGIN	FORM	ENERGY	TRAVEL IN AIR	OTHER CHARACTERISTICS
Alpha	Disintegrating nucleus	Particle	4 - 8 Mev	2-8 cm	Large, non-penetrating dangerous by ingestion or inhalation
Beta	Disintegrating nucleus	Negatron positron	0.02 - 4.8 Mev	0-10 m	Almost no mass, penetrating, release of kinetic energy
Gamma	Transformation of nucleus	Electro-magnetic	10 kev -3 Mev	100 m	Low mass, highly penetrating
X-rays	Transformation of orbital electron	Electro-magnetic	10 ev -120 kev	great	Low mass, highly penetrating

20.4.1 ALPHA PARTICLE EMISSION

If the neutron to proton ratio is too low, the atomic decay will generate -particles. An alpha particle () is a massive, highly energetic nuclear fragment positively charged helium nucleus, consisting of two protons and two neutrons. These are positively charged helium nuclei. Atoms with a high atomic weight are capable of generating -particles; -emissions may also be the by-product of other decay schemes.

Radium decay generates -particles as well as radiation:

$$^{226}_{88}\text{Ra decays in three steps to } ^{222}_{86}\text{Rn} \quad + \quad ^{4}_{2}\alpha \quad + \quad \text{two } \gamma \text{ rays}$$

Because of their size, alpha particles are limited in their ability to penetrate matter. The dead outer layer of skin covering the entire body is sufficiently thick to absorb all alpha radiation. Alpha particles are extremely hazardous when deposited internally, however the inability to penetrate clothing or the dead surface layer of skin minimizes the risk of external exposure to alpha radiation.

20.4.2 BETA EMISSIONS

Beta particles may be either positively or negatively charged.

β- negatrons are electrons which are ejected from the nuclei of radioisotopes which have a surplus of neutrons. An antineutrino is also ejected during the decay, but it is not charged (not ionizing). The negatron has a single negative electrical charge (-1.6×10^{-19}C) and a very small mass (0.00055 amu). Beta particles do not penetrate to the body core but can produce significant radiation damage to the skin. High energy Beta particles can damage the lenses of the eyes and produce significant skin doses. When a - negatron passes from one medium to another, excess energy may be dissipated as a blue-white glow. This is called the Cerenkov effect.

$^{32}_{15}P$ decays to $^{32}_{16}S$ + β- + antineutrino

When a β-negatron passes near a positively charged nucleus, the attraction from this nucleus causes the negatron to slow down. The energy lost during this 'braking' is given off in the form of low energy x-rays, called bremsstrahlung radiation. The energy of the bremsstrahlung may be anywhere from 0 to the original -energy. Use shielding material composed of atoms with low atomic number, such as hydrogen, carbon and oxygen, to minimize the energy and intensity of the bremsstrahlung. Plexiglass is the shielding of choice.

β+ positrons are beta particles with a single positive charge ($+1.6 \times 10^{-19}$ C) and the same mass as a negative electron (0.00055 amu).β+ positrons are emitted from nuclei in which the neutron to proton ratio is very low, but where emission is not energetically possible. β+ positrons are classified as antimatter and quickly undergo an annihilation reaction with an electron. This annihilation reaction generates radiation which is the principle hazard from this type of decay. This type of radioisotope therefore requires lead shielding.

$^{22}_{11}Na \rightarrow {}^{22}_{10}Ne$ + β+ + neutrino ➔ annihilation gives 2 γ (0.511 MEV)

20.4.3 GAMMA RAYS

Gamma rays () usually occur naturally, but may also result from research activities. Gamma rays originate in the nucleus of an atom. They are the energy released by nuclear rearrangement of neutrons and protons. Gamma emission is the mechanism by which a nucleus loses energy to go from a high energy excited state to a low energy stable state. Gamma rays are highly penetrating and require shielding with a dense material such as lead.

20.4.4 X-RAYS

-rays are generated outside the atom's nucleus. They may occur naturally, but are usually man-made. Naturally occurring x-rays are by-products of nuclear decay. X-rays are generated by rearrangement in the orbital electron cloud of an atom, usually in the K shell. X-rays have less energy than gamma rays. They are penetrating and can cause physical damage and therefore require shielding with a dense material such as lead.

20.5 BIOLOGICAL EFFECTS OF RADIATION

The biological effects of ionizing radiation can be either acute (deterministic) or delayed (stochastic). The biological effects will vary depending on radioisotope, target organ, time of exposure, location of exposure, etc.

The amount of kinetic energy of a radiation is the main determinant of its biological effect. High energy radiation impacting the body can cause a series of effects in different molecules as the energy is transferred from one atom to another.

20.5.1 ACUTE EFFECTS

Most of our understanding of the biological effects of radiation is due to the acute effects suffered by the early researchers and victims of nuclear testing and warfare. The first biological effect is usually a change in the white cell count. This effect is visible around 25 rems, or 50 times the annual dose limit for the general public (see Section 11).

20.5.2 DELAYED EFFECTS

The delayed effects of exposure to low level radiation include genetic effects which may take years to manifest, such as the development of cancers. At very low levels, such as those used in research, it becomes very difficult to distinguish the effect of occupational exposure to radiation from the effect of naturally occurring background radiation. Since all users at the University are considered to be members of the general public for dosimetry purposes, it is generally presumed that users have the same risk level as the general public.

20.6 MEASURING RADIATION EFFECTS

A variety of units are used to measure the radiation dose, how much of that dose is absorbed by an object and the effect of the absorbed dose if that object is living tissue. Both SI and non-SI units are presented here.

20.6.1 UNITS OF RADIATION DOSE

The milliroentgen (mR) is the unit used for the display or readout of most survey meters and portable detection units. The Coulomb/kilogram unit is not widely used.
The roentgen (R), is defined as the quantity of radiation that produces ions carrying one statcoulomb of charge of either sign per cubic centimetre of air at 0γC and 760 mm Hg. One roentgen corresponds to an absorption of 87.7 ergs per gram of air. One C/kg is approximately equal to 3876 roentgens and one roentgen is approximately equal to 258 microcoulomb/kg (μC/kg).

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

20.6.2 UNITS OF ABSORBED DOSE

The SI unit used to measure the energy imparted to irradiated matter is called the gray (Gy). It is defined as the absorbed radiation dose of one joule per kg.

The RAD (Radiation Absorbed Dose) was developed before the gray, and is defined as an absorbed radiation dose of 100 ergs/g or 0.01 Joules/kg.

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

20.6.3 UNITS OF RELATIVE BIOLOGICAL EFFECTIVENESS

The Sievert (Sv) is a SI unit that takes into account the biological effect of the particular radiation emission and the absorbed dose. It is defined as the numerical product of the absorbed dose in grays, multiplied by a quality factor. The Sievert replaces the rem where:

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

21. SAFE HANDLING PRACTICES

YOUR EXPERIMENTAL DESIGN AND LABORATORY WORK HABITS WILL DETERMINE THE RADIATION DOSE YOU AND YOUR CO-WORKERS RECEIVE!

Radioisotope users at the University must minimize the radiation dose received by themselves, co-workers and the general public. Users should follow the ALARA principle. The ALARA principle refers to the philosophy of striving to achieve the lowest possible dose taking into account economic and social factors. The term reasonable is included because the effort associated with reducing the dose received to a lower level will reach a point where it would be more effectively spent reducing the risk of other occupational health and safety hazards. One example of this is the use of lead aprons, where the risk of back injury often outweighs the radiation risk.

A As
L Low
A As
R Reasonably
A Achievable

In order to minimize the external radiation dose received, there are three factors which may be addressed: **time**, **distance** and **shielding** required.

21.1 TIME

Reducing the time spent near a radioisotope will directly reduce the dose received. This includes both work and storage.

$D = d*t$ D - radiation dose received
d - dose rate
t - time of exposure

21.2 DISTANCE

If time and dose rate are constant, the radiation dose received decreases in proportion to the square of the distance from the radiation source. In practice, this means that doubling your distance from the source will reduce your dose received to 1/4 of the original dose. This is referred to as "the inverse square law".

$$D_1 * S_1^2 = D_2 * S_2^2$$

Where S is the distance
D is the dose

21.3 SHIELDING

The term shielding refers to barriers that are set in place between the source of radiation and the recipient in order to reduce the dose received. Remember that radiation travels in all directions from its source and it is necessary to shield all sides. Shielding may stop all the radiation or only some depending upon the type of radiation as well as the type and quantity of shielding material. All materials, including air, offer some shielding, but the amount of protection afforded depends on the density and thickness of the material. The greater the density or the distance travelled through the material, the more likely it is that a radioactive emission will be absorbed.

TABLE 21.3 MINIMUM SHIELDING REQUIRED		
NUCLIDE	**DECAY**	**SHIELDING REQUIRED**
^{3}H	β	None required
^{14}C	β	None required
^{22}Na	β and γ	lead brick or lead lined glass
^{32}P	β	plexiglass
^{35}S	β	None required
^{45}Ca	β	3 mm plexiglass for more than 370 MBq (1 mCi)
^{51}Cr	γ	None required for less than 1 mCi
^{54}Mn	γ	lead brick or lead lined glass
^{57}Co	γ	1.7 mm lead
^{60}Co	β and γ	10 cm lead
^{63}Ni	β	None. ECD housing is adequate
^{86}Rb	β	plexiglass
^{99}Tc	β and γ	2.5 cm lead
^{125}I	γ and x-ray	lead lined glass
^{131}I	β and γ	6 cm lead

21.3.1 ALPHA PARTICLES

Alpha particles are easily absorbed. A few centimetres of air or a sheet of paper can stop these particles.

21.3.2 BETA PARTICLES

Beta particles are stopped by a few meters of air or a few millimetres of plexiglass. Use a shielding material of low mass number (ie. plexiglass), **do not use lead** shielding as this may cause bremsstrahlung radiation and can increase rather than reduce the risk.

21.3.3 GAMMA AND X-RAYS

Lead shielding is commonly used for Gamma radiation and x-rays. Lead aprons are designed for work with x-rays and are not recommended for work with gamma emitters because of the possibility of back injury. The use of lead bricks for shielding gamma emitters is recommended. The shielding requirements can be calculated using the exposure rate (without shielding) and the Half-Value Layer. One half value layer is the thickness of lead shielding required to reduce the dose by 1/2. The radiation energies of different isotopes are outlined in Section 24.

The dose received from radiation can be calculated according to the following equation:

$$D = \Gamma \underline{At}$$

d^2

Where D is the dose received
Γ is the ray constant in $(mSv*cm^2)/(h*MBq)$
A is the activity in MBq
t is the exposure time in hours
d is the distance from the source in cm

TABLE 21.3.3 HALF VALUE LAYERS	
GAMMA RADIATION ENERGY (MeV)	**mm OF LEAD**
0.5	4
1	11
1.5	15
2	19

21.4 EXPERIMENTAL DESIGN

Experimental design, proper planning and simply thinking about what will be done are the easiest ways to reduce the risk of exposure to radioisotopes. Design each experiment to reduce radiation dose received by:

- reducing the exposure time;
- using the minimum amount of activity necessary to the experiment;
- increasing the distance from the isotope; and
- introducing shielding.

Accidental exposures can be minimized in preparing for the experiment by:

- labeling all areas where radioactivity will be used;
- having all necessary material/equipment available;
- being prepared to react to an emergency situation; and
- performing a cold run (no radioisotope) of the manipulation.

After performing a cold run or an experiment assess how the experimental procedures could be improved. Ask yourself: Why did a problem occur? How to avoid the same problem next time? What other problems could be avoided?

If you have any questions or concerns do not hesitate to discuss your experimental procedures with the Radiation Safety Officer. The Radiation Safety Officer has years of experience and access to information from a variety of sources; he/she may be able to suggest possible alternatives.

21.5 OPEN SOURCE

There are precautions specific to the isotope and chemical form you will be using (see Section 24). Permit holders are required to inform users listed on their permit of safe practices specific to their laboratory and isotope. In general, you can maximize personal safety against an internal dose by:

- preventing ingestion; do not eat or drink in lab;
- preventing absorption; wear gloves and bandage cuts; and

- preventing inhalation; if aerosol hazards exist, use a fumehood.

21.6 SEALED SOURCE

There are precautions specific to the type of source you will be using, especially depending on whether the source you are using is enclosed within an instrument. Permit holders are required to inform users listed on their permit of safe practices specific to their laboratory and isotope. Remember that sealed sources can leak. It is therefore appropriate to take precautions such as wearing gloves, which would reduce the risk of ingestion, inhalation or absorption if the source were leaking.

22. MEASUREMENT

The radiation emitted by decaying isotopes can be measured. The efficiency of measurement depends on the type of detection equipment used as well as the type of decay product. The number of atomic disintegrations which the measuring equipment can detect is referred to as the counts per minute (cpm). The measuring equipment will not normally be able to count every single disintegration which occurs. This may be because products are emitted in all directions, not only in the direction of the detector. The equipment may not also be able to register all the products which impact it, due to technical design constraints. Air or other matter may stop some of the decay products from ever reaching the detector. It is also useful to remember that some decay products may interact with the detector to give false readings.

22.1 UNITS

The actual number of disintegrations occurring in a radioactive source is referred to as disintegrations per second (dps) or disintegrations per minute (dpm). The SI unit for radioactivity is the Becquerel (Bq), the standard units are the Curie (Cu). A Bq is equal to one disintegration per second. The Curie is the number of disintegrations occurring in 1 second for 1 gram of pure Radium (^{226}Ra), as measured by Madame Curie in 1910. The exact number value of the Curie was defined as 3.7×10^{10} dps in 1950.

1 Bq = 27 pCi = 1 dps
1 μCi = 37 kBq = 2.2×10^6 dpm

22.2 COUNTING EFFICIENCY

The proportion of cpm/dpm is called the counting efficiency, and is usually expressed as a percentage. The counting efficiency of an instrument is calculated by counting a source of known radioactivity and comparing the results with the theoretical dpm.

EXAMPLE: 10 uCi of a stock solution of a radioisotope which the detector is capable of counting.

$$\frac{1 \text{ dps}}{2.7 \times 10^{-12} \text{ Ci}} = \frac{X}{10 \times 10^{-6} \text{ Ci}}$$

X = 370,370 dps
= 370,370 dps x 60 s / min
= 22,222,220 dpm

The theoretical number of decays is 22,222,220 dpm
but it only detects 3,333,330 cpm with a background of 100 cpm

Therefore the detector efficiency is $= \frac{3,333,330 \text{ cpm} - 100 \text{ cpm}}{22,222,220 \text{ dpm}} = 15\%$

22.3 LIQUID SCINTILLATION

Liquid scintillation cocktail contains small amounts of one or more dissolved fluors. The energy emanating from radioactive decays may, either directly or indirectly, excite the fluor molecules and cause them to produce photons of visible light. Each decay particle may have enough energy to generate many photons, making this a very sensitive assay system for certain radioisotopes. Low energy $^-$ emitters such as ^{14}C can be counted efficiently, although ^3H may have as little as 30% counting efficiency.

The spectrum of the light peak generated by the fluorescence varies depending on the energy of the radioactive emission which caused it. These variations can be analysed by different channels of the counting instrument. The channel ratio can then be used to distinguish between the different isotopes present within a mixture.

High energy - emitters may be counted using the Cerenkov effect. Aqueous cocktails can be used to count Cerenkov radiation, but have a very low efficiency. Cerenkov counting is highly vulnerable to colour quenching.

The term quenching refers to any mechanism which causes the fluorescence of the cocktail not to reach the detector.
Some of the most important types of quenching are: chemical, dilution, colour, optical, or self-quenching. It may be necessary to choose another cocktail if quenching is affecting your readings.

High energy radioactive emissions such as and x-rays are usually not counted very efficiently since the emissions pass right through the liquid without affecting very many fluor molecules.

22.4 SOLID SCINTILLATION

Solid fluors are used to detect and x-rays. These emissions are more likely to interact with the crystal as the molecular structure is dense. These counters do not require the addition of a liquid scintillation cocktail. The emission interacts directly with the fluor crystal to produce photons.

22.5 GEIGER-MULLER DETECTORS

Geiger-Muller tubes are filled with an inert, ionizable gas such as helium, argon or neon at low pressure (1/10 atmosphere). The tube has a thin mica window at one end and an insulated wire which acts as an anode in the centre. If a radioactive decay product is sufficiently energetic, it will pass through the window and ionize some of the gas molecules which it encounters. This will lead to a cascade effect and ultimately, enough ionized gas molecules to trigger a pulse in the wire anode. The pulses are measured by a meter and displayed.

Geiger tubes are used to detect energetic $^-$ emissions, but a sufficiently thin window will permit the detection of ^{14}C decay. Low energy $^-$ emissions (^3H) and particles are not usually energetic enough to pass through the window. Geiger tubes are only about 1% efficient in detecting radiation and x-rays, which are energetic enough to pass right through the tube.

23. PREGNANCY

All workers at the University are considered to be members of the general public when determining the maximum permissible radiation dose. As such, there is no difference between the maximum amount of radioactivity a pregnant or non-pregnant worker can receive.

Workers at the University are to notify the Radiation Safety Officer as soon as they suspect a pregnancy. If necessary, the Radiation Safety Officer will keep this in confidence, but workers are also advised to inform their permit holder/supervisor immediately.

The worker may wish to reduce her exposure to radiation during her pregnancy and any specific concerns should be addressed to the permit holder or to the Radiation Safety Officer.

The Radiation Safety Officer will advise the pregnant worker regarding enrolment in the pregnancy dosimetry service offered by Health Canada.

24. RADIOISOTOPE SPECIFIC INFORMATION

This section includes information about the energy, toxicity and other considerations which vary depending on the radioisotope. Only information regarding radioisotopes commonly in use at the University has been included. If you have questions regarding a specific radioisotope, please contact EHSS. The information in this section was provided by Amersham Canada.

TABLE 24.1 HALF-LIVES AND RADIATION PRODUCED BY SOME RADIOISOTOPES

NUCLIDE	HALF-LIFE ($T_{1/2}$)	EMISSION ENERGY (Mev)		
		BETA (maximum)	POSITRON (maximum)	GAMMA OR X-RAYS
H-3	12.3 years	0.018	1.820	0.511 ; 1.275
C-14	5730 years	0.156	0.327	0.320
Na-22	2.6 years	1.710		0.122
P-32	14.3 days	0.167		1.17 ; 1.33
S-35	87.9 days	0.252		0.511 ; 1.115
Ca-45	165 days	1.148 ; 0.3		1.078
Cr-51	27.8 days	0.067		0.140
Co-57	270 days	1.780		0.173 ; 0.247
Co-60	5.2 years	0.806		0.035
Ni-63	92 years			0.364 ; 0.637
Zn-65	245 days			
Rb-86	18.6 days			
Tc-99m	6 hours			
In-111	2.81 days			
I-125	60.2 days			
I-131	8.05 days			

25. RADIOISOTOPE ACTIVITY EQUIVALENT TO ONE SCHEDULED QUANTITY

The Scheduled Quantity (SQ) is determined by the radiotoxicity of the radioisotope. Radiotoxicity is determined by the energy and type of radiation emitted, radioisotope half-life, and which organs may accumulate the radioisotope. The SQ are listed in CNSC regulations. Some of the radioisotopes commonly used at the University are listed in Table 25.

TABLE 25 SCHEDULED QUANTITIES OF RADIOISOTOPES USED AT THE UNIVERSITY

RADIOTOXICITY	ACTIVITY	RADIOISOTOPE
Slight	1000 uCi (37 MBq)	Hydrogen-3
Moderate	100 uCi (3.7 MBq)	Carbon-14 Chromium-51 Iron-55
Moderate-high	10 uCi (370 kBq)	Calcium-45 Chlorine-36 Cobalt-57 Iron-59 Phosphorous-32 Potassium-42 Rubidium-86 Sodium-22

		Sulphur-35
High	1 uCi (37 KBq)	Iodine-125 Iodine-131 Phosphorous-33

26. REGULATIONS GOVERNING THE USE OF RADIOISOTOPES

Radioactive materials are strictly regulated in Canada. EHSS liaises with the various regulatory agencies and is knowledgeable of regulations which may affect researchers at the University. EHSS cooperates with the Radiation Safety Committee and the Radiation Safety Officer to develop policies and procedures which govern radioisotope use at the University. This reduces the paperwork that individual researchers must do in order to ensure compliance with the regulations outlined in Section 26.2.

26.1 REGULATORY AGENCIES

There are numerous federal, provincial, regional and municipal agencies whose regulations may affect radioisotope use at the University. These include the Atomic Energy Control Board, the Ontario Ministry of Labour, the Regional Municipality of Ottawa-Carleton and others.

TABLE 26.1 REGULATORY AGENCIES		
AGENCY	**LEVEL**	**REGULATES**
CNSC	Federal	Acquisition, use and disposal of radioactive material.
Transport Canada	Federal	Transportation of radioactive material.
Ministry of Labour	Provincial	X-ray emitting devices and general work place safety.
Regional Municipality of Ottawa-Carleton	Regional	Disposal of chemicals to sanitary sewer system.
International Air Transport Association (IATA)	International	International air transportation of radioactive materials.

Other agencies may regulate the use of radioactive materials under certain circumstances. These include:

IAEA (International Atomic Energy Agency)
ICRP (International Commission on Radiological Protection)
BEIR (Advisory Committee of Biological Effects of Ionizing Radiation)

26.2 REGULATIONS GOVERNING THE USE OF RADIOACTIVE MATERIALS

The CNSC has issued both regulations (R-nn) and consultative documents (C-nn). The regulations have the power of law, including fines and jail terms. In addition, the use and transport of radioactive materials is legislated under the Transportation of Dangerous Goods regulations. Major regulations governing the use of radioactive materials in Canada are outlined in Table 26.2.

TABLE 26.2 REGULATIONS GOVERNING THE USE OF RADIOACTIVE MATERIALS		
DESIGNATION	**NAME OF REGULATION**	**DESCRIPTION**
	Atomic Energy Control Regulations	Address a wide variety of areas of concern regarding radiation, such as: records and inspections, security, health and safety.
Registration SOR/89-426	Transport Packaging of Radioactive Materials Regulation	Regulations respecting the packaging and safety marking of radioactive materials for transportation.

TABLE 26.2 REGULATIONS GOVERNING THE USE OF RADIOACTIVE MATERIALS		
DESIGNATION	**NAME OF REGULATION**	**DESCRIPTION**
R-52 June 7,1991	Design Guide for Basic and Intermediate Level Laboratories	Sets out the requirements for the design of radioisotope laboratories. Laboratories may be classified as either basic or intermediate.
R-58 September 15, 1983	Bioassay Requirements for ^{125}I and ^{131}I in Medical, Teaching and Research Institutions	Describes the minimal acceptable features of a bioassay program designed to monitor and ensure that no individual working with Iodine- 125 or 131 receives a thyroid burden in excess of regulatory limits.
R-91 March 1, 1990	Monitoring and Dose Recording for the Individual	Outlines the conditions under which monitoring of a radiation dose is required.
R-116 January 9, 1995	Requirements for Leak Testing Selected Sealed Radiation Sources	Describes the minimum requirements for leak testing a sealed source by means of a wipe test or radioactive measurement of the sample.

27. REGULATORY REQUIREMENTS

The use of radioactive materials is strictly legislated in Canada. The CNSC regulations outlined in Section 26 require certain conditions to be fulfilled. The General Conditions of the University of Ottawa Consolidated License have been summarized below.

27.1 GENERAL CONDITIONS - OPEN SOURCE

GENERAL

G-1 This permit shall be conspicuously posted in all locations listed on the permit.

G-2 It is the responsibility of the permit holder to ensure that all information listed on the Internal Radioisotope Permit is accurate and up to date. The permit holder shall request an amendment to the permit before said amendments are required and adopted.

G-3 All authorized radioisotope laboratories shall be kept locked when not in use.

G-4 The permit holder shall immediately inform the Environmental Health and Safety Service of any losses, thefts, or unaccountability of radioactive materials.

USE LIMITS & POSSESSION LIMITS

UPL-1 The use of radioisotopes shall be confined to the Use Limit specified on the Internal Radioisotope Permit for each procedure and shall conform to requirements on Table 1.

UPL-2 The permit holder may possess up to ten (10) times the use limit as long as each stock vial does not exceed 1000 Scheduled Quantities in the case of a Basic Level Laboratory, or 10,000 Scheduled Quantities in the case of an Intermediate Level Laboratory. Regardless of laboratory designation, the external radiation levels shall not exceed 2.5 mR/hr (25 uSv/hr). Each stock vial may not exceed the Use Limit specified on the Internal Radioisotope Permit.

UPL-3 Radioisotope procedures in excess of 100 Scheduled Quantities shall be carried out in a fumehood or approved laminar flow hood.

RADIATION PROTECTION MEASURES

RPM-1 Each permit holder shall establish, implement and maintain procedures designed to ensure that all occupational radiation doses are as low as reasonably achievable.

RPM-2 Each permit holder or their designate shall ensure that all areas where radioisotopes are used or stored shall not exceed a field strength of 2.5 mR/hr at 30 cm. Appropriate shielding shall be interposed, and in whatever quantity in order to reduce field strength to a level below 2.5 mR/hr.

RPM-3 The permit holder shall ensure that all persons working with radioisotopes under authority of their Internal Radioisotope Permit are properly trained in safe handling, storage, and disposal procedures, and are informed of the associated hazards of radioactive materials.

RPM-4 All undergraduate students participating in experiments or procedures using radioactive materials shall be closely supervised and instructed in safe handling and disposal procedures.

RPM-5 The permit holder shall instruct authorized users under their authority of any specific hazards associated with a particular procedure within their laboratory.

RPM-6 The permit holder shall permit any authorized user under their authority to attend any radiation protection courses offered by the University in cases where instruction is deemed necessary to ensure the safety of such users. Attendance at such sessions shall be considered paid time.

DOSIMETRY

D-1 The permit holder or their designate shall ensure that all authorized users are provided with a thermoluminescent dosimeter where required under page 2 of the Internal Radioisotope Permit, and that such dosimeters are used properly by authorized users.

D-2 Any authorized user that becomes pregnant shall forthwith inform the permit holder and the Environmental Health and Safety Service. The authorized user shall participate in any additional dosimetry programs the Environmental Health and Safety Service deems appropriate. The authorized user and the permit holder shall comply with any additional protective measures with may be prescribed, and may include a modified work program for the duration of the pregnancy.

D-3 Authorized users conducting radioiodination procedures shall participate in monitoring programs. The permit holder or their designate shall inform the Environmental Health and Safety Service of their intent to carry out such procedures.

SIGNING/POSTING

SP-1 All areas in a radioisotope laboratory where isotopes are used or stored shall mark such areas with radioactive marking tape. Waste receptacles not destined for municipal landfill shall be marked.

SP-2 A radiation warning sign shall be mounted on all doors leading into radioisotope laboratories where either (i) the total quantity of all radioisotopes in storage exceed 100 Scheduled Quantities, or (ii) a radiation field strength, measured at 30 cm, exceeds 2.5 mR/hr.

SP-3 The appropriate CNSC Basic or Intermediate Level Laboratory Rules poster shall be posted in each room where radioisotopes are used or stored. The name and phone number of the responsible contact person shall be shall be entered in the space provided. The permit holder and all authorized users shall comply with these Rules.

INVENTORY & DISPOSITION

ID-1 The acquisition, use, and disposal profile shall be documented on Form 2: Inventory of Use and Disposition. All information on Form 2 shall be provided. A copy of Form 2 shall be forwarded to the Environmental Health and Safety Service upon total disposition of the radioisotope. The permit holder shall retain such records for three (3) years.

ID-2 Waste disposal shall be in accordance with the procedures outlined in this manual or any other practice agreed upon by the Environmental Health and Safety Service.

CONTAMINATION MONITORING

CM-1 Each permit holder or their designate shall initially construct a laboratory plan of all rooms under the exclusive control of the permit holder where isotopes are used, and shall specify on the plan, the exact location where isotopes are used, stored, or disposed of within that laboratory. The plan shall be updated to maintain ongoing accuracy.

CM-2 Contamination monitoring shall be conducted weekly, in the case of a Basic level laboratory, or, immediately following procedures using quantities in excess of 1000 scheduled quantities. Results of monitoring shall be documented on Form 3: Results of Contamination Monitoring-Monthly Log and shall be cross-referenced to the laboratory plan. Results shall be retained for a period of three (3) years.

CM-3 Where results indicate levels of contamination in excess of twice background, the responsible individual shall forthwith decontaminate such areas, and shall document results after decontamination on Form 3.

CM-4 Monitoring shall be conducted through wipe testing, OR, if a contamination survey meter is available, and its detection efficiency is a minimum of 20% for the isotope being monitored, may substitute for wipe testing. The type of monitoring shall be documented on Form 3.

CM-5 The permit holder or their designate is not required to conduct monitoring where the inventory indicates that isotopes have not been used in the previous seven calendar days. The contamination monitoring record for that shall be marked "no isotope use".

REPORTING

R-1 The permit holder shall inform the Environmental Health and Safety Service of his/her intent to discontinue radioisotope use whether permanently or temporarily (ie. sabbatical). The permit holder shall comply with any requirement imposed by the Environmental Health and Safety Service regarding decommissioning, disposition of retained records, and disposition of existing stocks of radioisotopes.

R-2 The permit holder shall forthwith report any required modifications to the Internal Radioisotope Permits.

R-3 The permit holder shall communicate his/her intent to transfer radioisotopes to another permit holder, institution, or destination outside Canada, to the Environmental Health and Safety Service. The permit holder shall not transfer isotopes until approval is granted by the Environmental Health and Safety Service. The permit holder shall comply with any requirement imposed by the Environmental Health and Safety Service.

R-4 The permit holder shall inform the Environmental Health and Safety Service of the receipt of radioactive materials from another permit holder, institution, or importation across an international border.

PROHIBITIONS

P-1 The permit holder shall not accommodate for the storage or consumption of food, beverages; or equipment for the preparation of food or beverages; cigarette smoking, or the application of cosmetics within areas where radioisotopes are used or stored.

P-2 The permit holder shall not transfer radioisotopes to a person not authorized to receive such isotopes, and includes individuals having had such privileges suspended by way of sanction under statutory law.

P-3 The permit holder shall not permit under-aged individuals into areas where radioisotopes are used or stored.

P-4 Radioisotopes shall not be transported in a private motor vehicle on a public road, either by the permit holder, his/her designate, or by request to University transport.

27.2 GENERAL CONDITIONS - SEALED SOURCE

GENERAL

G-1 This permit shall be conspicuously posted in all locations listed on the permit.

G-2 It is the responsibility of the permit holder to ensure that all information listed on the Internal Radioisotope Permit is accurate and up to date. The permit holder shall request an amendment to the permit before said amendments are required and adopted.

G-3 All authorized radioisotope laboratories shall be kept locked when not in use.

G-4 The permit holder shall immediately inform the Environmental Health and Safety Service of any losses, thefts, or unaccountability of radioactive materials.

RADIATION PROTECTION MEASURES

RPM-1 Each permit holder shall establish, implement and maintain procedures designed to ensure that all radiation doses are as low as reasonably achievable.

RPM-2 Each permit holder or their designate shall ensure that all areas where sealed sources are used or stored shall not exceed a field strength of 2.5 mR/hr at 30 cm. Appropriate shielding shall be interposed, and in whatever quantity in order to reduce field strengh to a level below 2.5 mR/hr.

RPM-3 The permit holder shall ensure that all persons working with sealed sources under authority of their Internal Radioisotope Permit are properly trained in safe handling and storage, and are informed of the associated hazards of radioactive materials.

RPM-4 All undergraduate students participating in experiments or procedures using sealed sources shall be closely supervised and instructed in safe handling procedures.

RPM-5 The permit holder shall instruct authorized users under their authority of any specific hazards associated with sealed source use within their laboratory.

RPM-6 The permit holder shall permit any authorized user under their authority to attend any radiation protection courses offered by the University in cases where instruction is deemed necessary to ensure the safety of such users. Attendance at such sessions shall be considered paid time.

DOSIMETRY

D-1 The permit holder or their designate shall ensure that all authorized users are provided with a thermoluminescent dosimeter where required under page 2 of the Internal Radioisotope Permit, and that such dosimeters are used properly by authorized users.

D-2 Any authorized user that becomes pregnant shall forthwith inform the permit holder and the Environmental Health and Safety Service. The authorized user shall participate in any additional dosimetry programs the Environmental Health and Safety Service deems appropriate. The authorized user and the permit holder shall comply with any additional protective measures with may be prescribed, and may include a modified work program for the duration of the pregnancy.

SIGNING/POSTING

SP-1 Sealed sources shall be marked with a radiation warning symbol, the activity and identity of radioactive material.

SP-2 Devices containing a radioactive material (ie. electron capture gas chromatograph, self shielded irradiator) shall be clearly and durably labelled with a radiation warning sign and the nature, activity and date of measurement of the radioactive material involved. A clearly visible sign shall be located on or near the device indicating the identity (name and job title) and telephone number of the contact person.

SP-3 A radiation warning sign shall be mounted on all doors leading into radioisotope laboratories where either (i) the total quantity of all radioisotopes in storage exceed 100 Scheduled Quantities, or (ii) a radiation field strength, measured at 30 cm, exceeds 2.5 mR/hr.

CONTAMINATION MONITORING

CM-1 Except for sealed sources containing radioactive materials of less than one (1) millicurie, leak tests capable of detecting the presence of 0.2 kilobecquerel (12,000 disintegrations per minute) of radioactive material shall be performed: (1) at least once every 12 months on each sealed source in a self-shielded irradiator or gas chromatograph; (2) at least once every 6 months on other sealed sources; and (3) immediately following any incident on sealed sources which could have been damaged as a result of the incident.

CM-2 Records of leak testing shall be maintained for at least 3 years. If removable radioactive contamination in excess of 0.2 kilobecquerel (12,000 dpm) is detected, the sealed source holder or sealed source shall be isolated, its use immediately discontinued, and the Environmental Health and Safety Service shall be notified.

REPORTING

R-1 The permit holder shall inform the Environmental Health and Safety Service of his/her intent to discontinue radioisotope use whether permanently or temporarily (ie. sabbatical). The permit holder shall comply with any requirement imposed by the Environmental Health and Safety Service regarding decommissioning, disposition of retained records, and disposition of sealed sources.

R-2 The permit holder shall forthwith report any required modifications to the Internal Radioisotope Permits.

R-3 The permit holder shall communicate his/her intent to transfer sealed sources to another permit holder, institution, or destination outside Canada, to the Environmental Health and Safety Service. The permit holder shall not transfer sealed sources until approval is granted by the Environmental Health and Safety Service. The permit holder shall comply with any requirement imposed by the Environmental Health and Safety Service.

R-4 The permit holder shall inform the Environmental Health and Safety Service of the receipt of sealed source from another permit holder, institution, or importation across an international border.

R-5 The permit holder shall inform the Environmental Health and Safety Service of His/her intent to dispose of any sealed source or device containing a sealed source. The permit holder shall comply with any instructions issued by the Environmental Health and Safety Service.

PROHIBITIONS

P-1 The permit holder shall not accommodate for the storage or consumption of food, beverages; or equipment for the preparation of food or beverages; cigarette smoking, or the application of cosmetics within areas where sealed sources are used or stored.

P-2 The permit holder shall not transfer sealed sources to a person not authorized to receive such sources, and includes individuals having had such privileges suspended by way of sanction under statutory law.

P-3 The permit holder shall not permit under-aged individuals into areas where sealed sources are used or stored.

P-4 Sealed sources shall not be transported in a private motor vehicle on a public road, either by the permit holder, his/her designate, or by request to University transport.

28. FORMS

A sample of each of the forms mentioned in this manual is included for reference.

TABLE 28 FORMS IN USE AT THE UNIVERSITY OF OTTAWA
▪ Individual Inspection Questionnaire
▪ Internal Radioisotope Permit Application (Open Source)
▪ Inventory of Use and Disposition (Form 2)
▪ Liquid Scintillation Waste Log
▪ Radioactive Solid Waste Log
▪ Radioisotope Laboratory Inspection Form - Open Source
▪ Radioisotope User Registration Form
▪ Record of Contamination Monitoring Monthly Log (Form 3)

29. RESOURCES AVAILABLE

The Environmental Health and Safety Service maintains a variety of resource materials pertaining to safety. These include videos and books covering radiation safety. These materials may be loaned to anyone who wishes to refresh their memory.

EHSS VIDEO LIBRARY

1 Introduction to Hazardous Materials

2 Managing the Hazardous Materials Incident

3 Understanding Explosives

4 Responding to Explosive Emergencies

5 Understanding Compressed and Liquified Gases

6 Understanding Cryogenics

7 Responding to Gas Emergencies

8 Understanding Flammable and Combustible Liquids

9 Responding to Flammable and Combustible Liquid Emergencies

10 Understanding Flammable Solids

11 Responding to Flammable Solid Emergencies

12 Understanding Oxidizers

13 Responding to Oxidizer Emergencies

14 Understanding Poisons

15 Responding to Poison Emergencies

16 Understanding Radioactive Materials

17 Responding to Radioactive Emergencies

18 Understanding Corrosives

19 Responding to Corrosive Emergencies

20 Miscellaneous Hazardous Material Emergencies

21 Incidents Involving Fuel Trucks
Diking, Diverting and Retaining Spills
Plugging and Patching Drums
Containing Leaks in Pressurized Cylinders

22 Hazmat First Responder Operations Training Series
1- Applying Basic Chemistry
2- Safety & the Nine UN/DOT Classes
3- Use and Care of Personal Protective Equipment

23 Hazmat First Responder Operations Training Series
4- Decontamination Procedures
5- Techniques for Control and Containment

24 First Response Series Hazardous Materials
1- Awareness
2- Identification
3- Pre-Incident Risk Analysis
4- Pre-Incident Action Plans
5- Incident Procedures

25 Fire Command in Action
Why Decontaminate
Decontamination Procedures
Handling Contaminated Victims

26 Les rayonnements et notre environnement

27 Radiation and our Environment

28 Practicing Safe Science

29 Set One (Radionuclide Hazards, Chemical Hazards, Emergency Response)
29A Radionuclide Hazards
29B Chemical Hazards
29C Emergency Response

30 Controlling your Risks - HIV in the Research Laboratory

31 Set Two (Centrifugation Hazards, Chemical Storage Hazards, Glassware Washing Hazards)
31A Centrifugation Hazards
31B Chemical Storage Hazards
31C Glassware Washing Hazards
31D Assessing Risks

32 Look Around: You Have Rights - "What Every Young Worker Should Know"

33 Children For Hire

34 Safety Care Series
1- Accident Investigation

35 Hazard Awareness Series
1- Controlling Exposure to Toxic Substance

36 An Introduction to Reactive and Explosive Materials

37 Bloodborne Pathogens

38 Hazardous Materials and Health and Safety at Work
38A Part One: Beware...Danger!
38B Part Two: W.H.M.I.S.
38C Part Three: Labels and Material Safety Data Sheets
38D Part Four: Prevention and First Aid

39 Glass Works (Glass Recycling)

40 Working Safety with Radioactivity

41 Due Diligence - Occupational Health and Safety Strategies for Senior Management

42 Comprehensive Management of Compressed Gases

43 Radiation Safety Series
43A Radiation Safety I: The Key to Contamination Control
43B Radiation Safety II: The Key to Contamination Detection
43C Radiation Safety III: The Key to Contamination Procedures