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RADIATION PROTECTION MANUAL

John FitzGerald

NWRI Technical Note No. TN06-002

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Environment Canada

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John FitzGerald

Canada Centre for Inland Waters
867 Lakeshore Road
Burlington, Ontario L7R 4A6

NWRI TN # 06-002

January 2006

CCIW Radiation Protection Manual

John FitzGerald

PREAMBLE

All activities involving the use of radioisotopes at the Canada Centre for Inland Waters (CCIW) complex are carried out in accordance with the rules and regulations promulgated by the Canadian Nuclear Safety Commission (CNSC) which achieves its control through the Nuclear Substances and Radiation Devices Licence issued to CCIW. All health and safety policies, procedures, standards and guides contained in this manual have been established by the CNSC. This manual is periodically updated to reflect changes in CNSC rules and regulations.

Manuel de la radioprotection du CCEI

John FitzGerald

PRÉAMBULE

Toutes les activités où sont utilisés des radioisotopes au Centre canadien des eaux intérieures (CCEI) sont exécutées conformément aux règles et règlements de la Commission canadienne de sûreté nucléaire (CCSN), laquelle exerce sa surveillance au moyen d'un permis de substances nucléaires et d'appareils à rayonnement délivré au CCEI. Les politiques, procédures, normes et guides en matière de santé et de sécurité qui figurent dans ce manuel ont été établis par la CCSN. Ce manuel est périodiquement mis à jour pour tenir compte des modifications des règles et règlements de la CCSN.

PREFACE

The value of good health of Public Service employees is recognized as a matter of primary importance by the Treasury Board. The basic safety policy underlying all Public Service activities is also issued by the Treasury Board, except for safety regulations concerning application and use of atomic energy made pursuant to the Canadian Nuclear Safety and Control Act. Accordingly, health and safety policies, procedures, standards and guides have been established by the federal regulator of nuclear materials, the Canadian Nuclear Safety Commission (CNSC). All activities involving use of radioisotopes at the CCIW complex are carried out in accordance with the rules and regulations promulgated by the CNSC which achieves its control through the consolidated licence. These rules and regulations have been extended to research vessels, trailers and field parties to further ensure the safety of all concerned, although it is recognized that some personnel aboard ships may exclusively come under the jurisdiction of the Canada Shipping Act. The radiation safety record of CCIW is excellent and it is the intent of the Centre to maintain a high standard of safety with the cooperation of each member of the staff.

CCIW Management Policy Statement

1. Accident prevention shall be a prime requisition of all operations.
2. Management will provide mechanical and physical safeguards and protective equipment in accordance with recognized standards.
3. Management will arrange for additional radioisotope use and safety training where deemed necessary by the CCIW Radiation Safety Committee (RSC) or the CNSC.
4. All components at the CCIW complex will be required to comply with all rules and regulations detailed in the CCIW Radiation Protection Manual or promulgated by the RSC in accordance with any new CNSC or other applicable Federal, Provincial and Municipal regulations.
5. Management and supervisory personnel will be held individually responsible for providing a safe working environment within their areas of responsibility to the same standards as their working duties are assessed.
6. All components of CCIW involved in the use or handling of radioisotopes will be represented on the RSC.
7. Management will maintain liaison with the CNSC through the CCIW Radiation Safety Officer.

Dr. John Carey
Director General
National Water Research Institute
Environment Canada

Vic Gillman
A/Regional Director, Science
Regional Science Director's Office
Fisheries and Oceans Canada

TABLE OF CONTENTS

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PREAMBLE

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PART 1

FUNDAMENTALS OF RADIATION PROTECTION

I. BASIC DEFINITIONS

In order to appreciate the origins, characteristics and relative hazards associated with nuclear radiations, some pertinent definitions are given below:

Fundamental Particles

The fundamental particles from which all atoms are constructed are called protons, neutrons and electrons. Their basic properties are summarized in Table 1.

TABLE 1

Particle	Relative Mass	Electric Charge
Electron	1	-
Proton	1836	+
Neutron	1839	Zero

The Atom

Atoms consist of an extremely dense nucleus of protons and neutrons, surrounded by a "cloud" of electrons. The nucleus constitutes approximately 99.9% of the mass of the atom. An atom normally has the same number of electrons as protons so that the net electric charge carried is zero.

The number of protons in the nucleus is called the atomic number (Z). The atomic number identifies an element. The mass number (A) of an atom is defined as $A = Z + N$, where N represents the number of neutrons in the nucleus. An atom of an element can be identified in general by ${}_{Z}^{A}X_{N}$, where X represents the chemical symbol for the element

EXAMPLE: ${}^{12}{}_6C_6$ represents an atom of carbon.

Isotopes

Atoms of an element are found to have different mass numbers. These different forms are called isotopes of the element, and differ from one another only in the number of neutrons in the nucleus.

EXAMPLE: ${}^{12}{}_6C_6$ and ${}^{13}{}_6C_7$ are isotopes of carbon, more commonly designated as ${}^{12}C$ and ${}^{13}C$, respectively.

Elements occur naturally as a mixture of stable isotopes. The isotopes of an element are chemically identical since the chemical properties of an atom are determined by the atomic number.

Radioisotopes

Not all isotopes of an element are stable. An unstable nucleus, or radioisotope, will undergo a spontaneous transformation into a more stable decay product. The transformation process is known as radioactive decay, and is accomplished by the emission of nuclear radiations. Radioactivity is a phenomenon which is independent of the chemical and physical states of the radioisotope. Radioisotopes of different elements have unique radioactive properties (Table 2).

EXAMPLE: ${}^{14}C$ is a radioisotope of carbon.

The number of radioisotopes known today exceeds 1250. The majority of radioisotopes are produced artificially by neutron activation of stable isotopes in a reactor. Only a small number of radioisotopes occur naturally. Naturally occurring radioisotopes contribute to the background radiation in which we live. In this regard, the most important radioisotopes include those members of the uranium and thorium series, and ${}^{40}K$. Naturally occurring radioisotopes of biological significance include ${}^{40}K$ and ${}^{14}C$.

TABLE 2. RADIOACTIVE PROPERTIES OF SELECTED RADIOISOTOPES

Radioisotope	Half-Life	Decay Mode	Energy in MeV	
^{3}H	12.26 y	Beta	0.018	(max)
^{14}C	5730 y	Beta	0.156	(max)
^{32}P	14.28 d	Beta	1.71	(max)
^{35}S	87.9 d	Beta	0.167	(max)
^{45}Ca	165 d	Beta	0.252	(max)
^{51}Cr	27.8 d	Electron capture,		
		Gamma	0.320	(9%)
^{59}Fe	45.6 d	Beta	0.475	(max)
		Gamma	1.095	(56%)
			1.292	(44%)
^{60}Co	5.26 y	Beta	0.314	(max)
		Gamma	1.173	(100%)
			1.332	(100%)
^{65}Zn	245 d	Electron capture,		
		Gamma	1.115	(59%)
			0.511	(3.4%)
^{125}I	60.2 d	Electron capture,		
		Gamma	0.035	(7%)
^{131}I	8.05 d	Beta	0.606	(max)
		Gamma	0.364	(82%)
^{137}Cs	30.0 y	Beta	0.514	(max)
		Gamma	0.662	(85%)
^{226}Ra	1620 y	Alpha	4.78	(94%)
			4.60	(6%)
		Numerous Beta and Gamma radiations		
^{241}Am	458 y	Alpha	5.49	(85%)
			5.44	(13%)
		Numerous Gamma radiations		

The Electron Volt

The energy of nuclear radiations is expressed in units of electron volts (eV). One electron volt is equivalent to the energy gained by an electron accelerated through an electrical potential difference of one volt. The electron volt is a very small unit of energy. Larger units of energy are multiples of the electron volt:

One kiloelectron volt (KeV) $= 10^{3}$ eV.

One megaelectron volt (MeV) $= 10^{6}$ eV.

The energies of most nuclear radiations range from several KeV to about six MeV.

The Joule

A joule (J) is a unit of work and equals 0.24 gram-calorie, or the amount of work produced in one second by one watt.

Nuclear Radiations

Alpha particle emission, beta particle emission and gamma radiation are the most important mechanisms of radioactive decay. As these nuclear radiations penetrate matter, they dissipate their energy through "collisions" with atomic electrons in the absorbing medium. The results of these interactions are the excitation and ionization of absorber atoms, and the disruption of molecular bonds. These effects may be detrimental to biological systems.

(i) Alpha Particle Emission

An alpha particle (α) is a positively charged assembly of two neutrons and two protons (a helium nucleus, ^{4}He) which is discharged from a heavy nucleus during radioactive decay. Alpha particles are the least penetrating of nuclear radiations. The range in air of the most energetic alphas is only several centimetres. Their range in tissue is insufficient to penetrate the 0.07 mm outer layer of skin (epidermis).

Alpha radiation from radioactive substances outside the body is harmless. However, internally deposited alpha emitting radioisotopes are highly toxic because all the energy of the radiation is deposited in living tissue. Uranium is an example of an alpha emitter. The high incidence of lung cancer among uranium ore miners has been attributed to the deposition of insoluble uranium particles and ^{222}Rn daughters in the respiratory system.

(ii) Beta Particle Emission

A beta particle (β) is an electron that is ejected from the nucleus upon the spontaneous transformation of a neutron into a proton. Beta particles exhibit a continuous energy distribution ranging from zero to a maximum energy characteristic of the particular beta-emitter. The average energy of a beta particle is approximately 1/3 of this maximum energy.

The interaction of beta particles with matter results in electronic excitation, ionization and the production of X-rays (Bremsstrahlung). Beta particles will penetrate matter to varying depths depending upon their energy and on the density of the absorber. They have a range in air of approximately 3.5 metres per MeV.

The hazards of beta radiation depend on the energy of the beta particles and the nature of any shielding. For most beta emitters, the container of the isotope is sufficient to reduce most of the radiation flux. The radiation from external sources emitting weak betas, such as ^{3}H and ^{14}C, is innocuous. However, any internally deposited beta-emitting radioisotope is potentially harmful to health.

(iii) Gamma Radiation

Both alpha and beta decay processes frequently leave a daughter nucleus in an "excited" state. A gamma ray (γ) is a photon ("packet") of electromagnetic radiation produced by the spontaneous de-excitation of an excited nuclear state, to a lower excited state, or to the ground state.

Gamma rays are the most penetrating of nuclear radiations and cannot be completely absorbed. Protection against gamma radiation often involves the reduction of intensity to acceptable levels by suitable thicknesses of appropriate absorbers. The absorptive properties of matter are functions of the atomic number of the absorber and the energy of the gamma radiation. Materials of high atomic number such as lead (Z = 82) are preferred absorbers of gamma radiation.

Gamma emitters always present a potential external radiation hazard because of the penetrating nature of their radiation. Protective measures are essential for the safe handling of gamma sources.

Activity

The activity (A) of a radioactive material refers to the rate of disintegration of the unstable nuclei. The common unit of activity is called the curie (Ci). One curie equals 3.7×10^{10} disintegrations per second. The new SI unit of activity is called the becquerel (Bq) and equals one disintegration per second.

The curie is an enormous unit of activity. Common submultiples of the curie are shown in Table 3 along with corresponding SI units.

TABLE 3.

Unit	Ci	SI Unit
millicurie (mCi)	10^{-3}	37 MBq
microcurie (µCi)	10^{-6}	37 kBq
nanocurie (nCi)	10^{-9}	37 Bq
picocurie (pCi)	10^{-12}	37 mBq

Half-Life

The half-life ($t_{1/2}$) of a radioisotope is the time required for one half of the unstable nuclei to decay. If the activity of the sample is A_0 at time t = 0, then the activity remaining after one half-life is 1/2 A_0. Figure I illustrates the decrease of activity with time.

An expression for the relationship shown in the figure is

$$A = \frac{A_0}{2^n}$$

where n is the number of half-lives elapsed since t = 0.

Another useful equation is the logarithm form using the decay constant, 8 (= $0.693/t_{1/2}$):

$$\log_{10} A = \log_{10} A_0 - 0.4343\ 8\ t$$

The half-lives of different radioisotopes range from about 10^{-8} seconds to 10^{9} years.

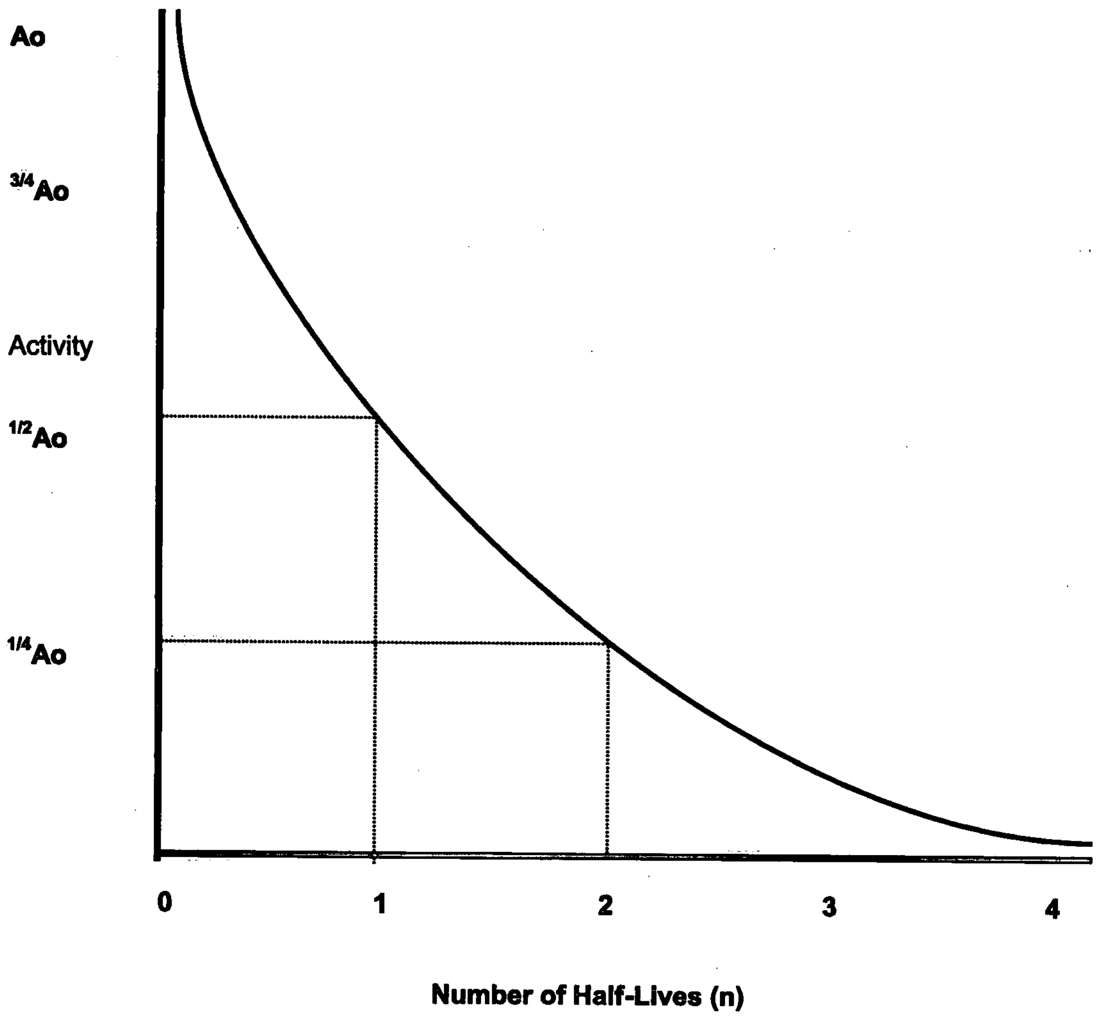

FIGURE I

EXPONENTIAL DECAY OF RADIOISOTOPES

Although the half-lives of radioisotopes differ, they all decay in this predictable fashion. ^{131}I ($t_{1/2}$ = 8 days) will lose 87% of its activity in 24 days (n = 3). ^{14}C will lose only half of its activity after 5730 years (n = 1).

II. RADIATION DOSE

A. RADIATION DOSE UNITS

1. Absorbed Dose

Radiation resulting from a nuclear transformation is commonly referred to as "ionizing radiation" since it has enough energy to knock an electron out of an atom or molecule, a process known as ionization. This ejected electron, in turn, may collide with other atoms and either eject more electrons or excite the atom. So, as the radiation passes through matter, energy is transferred to the matter by these processes, resulting in a track of ionized and disrupted molecules. These may then recombine in different ways, resulting in structural changes and perhaps ultimately in biological effects. The unit of absorbed dose is related to the energy deposited, and the basic unit is known as the Gray (Gy) in the SIU system.

1 **Gray** = 1 joule per kilogram

Another unit of absorbed dose still in widespread use is the rad.

1 **rad** = 100 ergs per gram = 0.01 joules per kilogram (therefore 100 rads = 1 Gray)

2. Equivalent Dose

In humans, it is found that the extent of biological damage depends not only upon the amount of energy deposited per unit mass in the system, but also upon the energy is distributed within that unit mass. For the same total amount of energy deposited, those radiations which produce a dense track of ionized and excited molecules are more effective at promoting biological changes that those radiations which produce a more widespread distribution of ions. To take this into account, the absorbed dose in Grays (or rads) is multiplied by a scaling factor called the Radiation Weighting Factor (once known as the Quality Factor QF). This factor is 1 for the most common radiations (beta particles, X- and gamma-rays) and can range up to 20 for heavy charged particles. A complete list of Radiation Weighting Factors is given in Appendix A. The dose resulting from the product of the absorbed dose in Grays (or rads) and the Radiation Weighting Factor is now a measure of biological damage and not just the energy deposited. This unit of dose is the **Sievert** (or **rem**).

Dose in **Sieverts (Sv)** = Dose in **Grays x Radiation Weighting Factor**

Dose in **rem** = Dose in **rads x Radiation Weighting Factor**

Example:

Assume you had 1 joule of energy per kilogram deposited uniformly throughout your body. Your absorbed dose is 1 Gray. If the radiation depositing the energy were X-rays, gamma-rays, or β-particles, your dose would be 1 Sv since the Radiation Weighting Factor is 1 for these radiations, and so 1 Gy = 1 Sv. If the radiation depositing the energy were alpha particles with a Radiation Weighting Factor of 20, your dose would be 20 Sv (1 Gy x 20). That is, although the energy deposited was the same in both cases, the biological effect from the alpha particles would be 20 times greater than for the other radiations.

3. The Roentgen

Yet another radiation unit still commonly encountered is the roentgen (r), named after the discoverer of X-rays. For all practical purposes, rads, rems, and roentgens can be used interchangeably when dealing with X-rays or gamma-rays.

4. Effective Dose

What happens when you receive a dose of 1 Sv to your thyroid, and a friend receives a dose of 1 Sv to each of the thyroid and lung? It seems intuitively wrong to claim that you both received identical doses of 1 Sv. It also seems wrong to claim your friend received a total dose of 2 Sv. Obviously your friend has a higher probability of biological damage than you and this should be taken into account when the doses are calculated. We do this by multiplying the dose to each organ by a **tissue weighting factor** for that organ and add up these weighted sums to obtain the **effective dose**. Tissue weighting factors are given in Appendix A. These weighting factors are essentially relative radiosensitivities, and are the values adopted by the ICRP in 1990. In your case of the thyroid irradiation, your effective dose is 0.05 x 1 Sv x 0.12 (lung) for a total of 0.17 Sv. The effective dose is the dose which, if given uniformly to the whole-body, would put you at the same risk as the non-uniform dose that you actually received. That is, for you, a dose of 1 Sv to the thyroid is equivalent in risk to 0.05 Sv received by each and every organ and tissue in the body. For your friend, the dose of 1 Sv to each of the lung and thyroid resulted in a risk equivalent to a uniform whole-body exposure of 0.17 Sv.

If the whole body is uniformly irradiated, which is the usual case except for an intake of a radioisotope, then the effective dose will be the same as the equivalent dose.

B. ANNUAL DOSE LIMITS

Dose limitation is based on risk. The underlying philosophy is that the limit on risk should be equal whether the whole body is irradiated or whether there is non-uniform exposure. Therefore, based on the preceding section, the limits will obviously be based on effective dose. The annual permissible exposures are given in Table 1 and in Appendix A. It should be emphasized that the values in Table 1 are limits, not goals. One of the basic radiation protection principles is ALARA -- As Low As Reasonably Achievable. In practice, you should reduce your exposure as much as is reasonable, even if it is already considerably below allowable exposures. Ionizing radiation may cause biological damage, and so there is no justification for receiving any dose that is not necessary.

Table 4. Effective Dose Limits

The CNSC states: "Every licensee shall ensure that the effective dose received by and committed to a person described in column 1 of an item of the table to this subsection, during the period set out in column 2 of that item, does not exceed the effective dose set out in column 3 of that item."

Item	**Column 1**	**Column 2**	**Column 3**
	Person	Period	Effective Dose (mSv)
1.	Nuclear energy worker, excluding a pregnant nuclear energy worker	a) One-year dosimetry period	50
		b) Five-year dosimetry period	100
2.	Pregnant nuclear energy worker	Balance of pregnancy	4
3.	A person who is not a nuclear energy worker	One calendar year	1

Table 5. Equivalent Dose Limits

For equivalent doses: "Every licensee shall ensure that the equivalent dose received by and committed to an organ or tissue set out in column 1 of an item of the table to this subsection, of a person described in column 2 of that item, during the period set out in column 3 of that item, does not exceed the equivalent dose set out in column 4 of that item."

Item	Column 1	Column 2	Column 3	Column 4
	Organ or tissue	Person	Period	Equivalent Dose (mSv)
1.	Lens of an eye	(a) Nuclear energy worker	One-year dosimetry period	150
		(b) Any other person	One calendar year	15
2.	Skin	(a) Nuclear energy worker	One-year dosimetry period	500
		(b) Any other person	One calendar year	50
3.	Hands and feet	(a) Nuclear energy worker	One-year dosimetry period	500
		(b) Any other person	One calendar year	50

C. BACKGROUND RADIATION

Our environment contains approximately 10 cosmogenic radionuclides (including ^{3}H and ^{14}C) and 16 primordial radionuclides in addition to the 46 radionuclides in the ^{232}Th, ^{235}U, and ^{238}U chains. These isotopes, which are present in soil, water, air and minerals, produce an external radiation dose. Isotopes present in the soil, water, and in the air eventually end up in the food chain, and so produce and internal radiation dose as well. An adult human body contains approximately 0.1 µCi (4kBq) of both ^{14}C and ^{40}K. In addition, one of the decay products of natural uranium is radon (^{222}Rn), an inert gas. It diffuses through the soil and can concentrate in dwellings. Its decay products are also radioactive, and they will be inhaled, resulting in a lung dose. Radon is the single largest source of natural radiation for the public.

We are also constantly bombarded by particles originating from outer space. This component of background radiation is called cosmic radiation. The earth's atmosphere acts as a shield and so cosmic radiation is greater at higher altitudes since there is less atmosphere to shield the radiation.

Typical background and medical doses are given in Table 2 and Table 3.

Table 6. Average Background Radiation

Source	Dose Equivalent (mSv)	Effective Dose (mSv)
Radon	24.0	2.0
Cosmic	0.27	0.27
Terrestrial	0.28	0.28
Internal	0.39	0.39
Total Natural	--	2.94

Table 7 . Typical Medical Exposures

Procedure	Effective Dose (mSv)
Chest radiograph	0.02-0.05
Skull radiograph	0.15
Thoracic spine radiograph	0.90
Pelvic/abdominal radiograph	1.3
Head CT scan	2.0
PET scan	3.9 (1.0-8.9)
Intravenous urogram	4.4
Average Tc-99m scan	5.0 (1.3-8.2)
Barium examination	3.8-7.7
Body CT scan	6-16

D. RISKS

There have been many situations in which large numbers of people have been exposed to high levels of radiation, and through studies of these, the health effects of high-level radiation are well known. The most important study is that of the survivors of Hiroshima and Nagasaki. Individual dose estimates have been made for 75,991 survivors through 1985. Of these, 34,272 received minimal doses and act as controls, while the remaining 41,719 received doses of 5 mGy or more. Of these, 3,435 have died from some form of cancer, and this is about 350 above the expected number. At the 95% confidence level, there are no excess cancers below doses of about 200 mSv. The revised dose estimates and the adoption of the relative risk model led to a revision of the risk factor for radiation in 1990. Undoubtedly, the risk factor will be revised in the future as our models improve and as better statistics are obtained.

There is some disagreement in the scientific community concerning how we should extrapolate the data from the A-Bomb survivors to lower levels of radiation and to lower dose rates. The conservative approach is normally taken by assuming that the biological effects are proportional to dose without a threshold. It should be noted that no study has demonstrated a biological effect from ionizing radiation at normal occupational doses. The controversy exists simply because the effect, if any, is so small. If the effect were large, then there would be no disagreement because the effect would be clearly observed.

Table 4 is based on a uniform whole-body dose of 1 mSv per year from gamma- or X-radiation for a population of 1,000 people. Remember that 1 mSv per year is comparable to background.

Table 8 . Total Lifetime Excess Cancer Mortality from Exposure to Radiation for an Initial Population of One Thousand Persons

Cancer Mortalities	Continuous exposure to 1 mSv/y from ages 18-65		Continuous exposure to 1 mSv/y for lifetime	
	Male	Female	Male	Female
Expected number without radiation	209.1	177.1	205.6	175.2
Excess due to radiation	1.6	1.7	3.0	3.3
% Increase	0.81%	0.95%	1.43%	1.88%

Based on "Health Effects of Exposure to Low Levels of Ionizing Radiation" (BEIR V)

It is natural to be concerned with the genetic effects of ionizing radiation. The International Commission on Radiological Protection is an independent body of international experts in a variety of disciplines which reviews the literature on the effects of ionizing radiation and makes recommendations that are almost universally accepted. It concludes "If the damage caused by radiation occurs in the germ cells, this damage (mutations and chromosomal aberrations) may be transmitted and become manifest as hereditary disorders in the descendants of the exposed individual. **Radiation has not been identified as a cause of such effects in man**, but experimental studies on plants and animals suggest that such effects will occur and that the consequences may range from the undetectably trivial, through gross malformations or loss of function, to premature death". The BEIR V commission concluded that "Results of these careful and very extensive studies, when taken at face value, suggest that humans may be somewhat less sensitive to radiation than mice". Table 5 is based on the assumption that the doubling dose in humans is the same as for mice, namely 1,000 mSv.

This table shows that the incidence of effects from radiation is very small compared to the natural incidence of genetic effects. BEIR V notes that "the greater current risk (of mutations) seems to result from exposure to chemical mutagens in the environment rather than from the exposure of populations to radiation".

Table 9 . Estimated Genetic Effects of 10 mSv per Generation

Type of Disorder	Current Incidence per Million Liveborn Offspring	Additional Cases per Million Liveborn	
		First Generation	Equilibrium
Autosomal Dominant			
Clinically severe	2,500	5-20	25
Clinically mild	7,500	1-15	75
X-linked	400	<1	<5
Recessive	2,500	<1	Very slow increase
Chromosomal			
Unbalanced translocations	600	<5	Very little increase
Trisomies	3,800	<1	<1
Congenital abnormalities	20,000-30,000	10	10-100

Based on BEIR V

In Table 6 the loss of life expectancy due to various causes is given. This table confirms your suspicions that life consists of many risks. The average loss of life expectancy due to an annual exposure of 1 mSv/y (100 mrem/y) is 10 days. This is marginally higher than the loss of life expectancy from drinking coffee.

Table 7 compares the minutes of life expectancy lost from various individual actions. Perhaps the simplest way of putting the loss of life expectancy from radiation is to equate 0.1 mSv with about four cigarettes or to driving 100 miles.

Table 10. Loss of Life Expectancy Due to Various Causes

Cause	Days	Cause	Days
Living in poverty	3,500	Dangerous job-accidents	300
Being unmarried-male	3,500	Motor vehicle accidents	207
Being unmarried-female	1,600	Accidents in home	95
Smoking-male	2,250	Average job-accidents	74
Smoking-female	800	Alcohol-average	130
Being 30% overweight	1,300	Legal drug misuse	95
Being 20% overweight	900	Radon in homes	35
Cancer	980	Radiation-1 mSv per year	10
Diabetes	95	Coffee	6
Drowning	41	Smoke alarm in home	-10

Table 11. Some Risks for Individual Actions

Individual Action	Minutes of Life Lost	Individual Action	Minutes of Life Lost
Smoking a cigarette	10	Coast to coast drive	1000
Crossing a street	0.4	Coast to coast flight	100
Driving	0.4/Mile	0.1 mSv radiation	40
Not using a seat belt	0.1/Mile	Skipping annual PAP test	6000

Finally, yet another way of putting your occupational radiation dose in perspective is to look at one-in-a-million risks of death from various causes. In Table 8, we see that if we receive 1 mSv per year of radiation at work, we have to work 50 hours to accumulate one chance in a million of death; in the manufacturing industry, we would have to work 17 hours to accumulate the same risk. To put a one-in-a-million risk in perspective, the lower portion of the table shows that a one-in-a-million risk is equivalent to driving 49 miles or eating 90 pounds of charcoal broiled steak.

E. ACUTE EFFECTS

It is highly unlikely that any individual at CCIW could receive a whole-body dose sufficiently large to produce an observable biological effect, although it may be possible to exceed the regulatory limits. However, as we will see, it is quite possible to receive a localized beta- or X-ray exposure large enough to produce observable effects if proper procedures are not followed. The biological effects from massive radiation exposures are described in Tables 9 and 10.

Table 12. One-In-A-Million Risks

Industry	Hours of Work for 1-in-a-Million Risk	Industry	Hours of Work for 1-in-a-Million Risk
Mining	1.5	Manufacturing	17
Forestry	1.7	Agriculture	37
Fishing	2.3	Trade	37
Construction	4.9	Service	53
Transport	6.6	Finance	125
Public Administration	16.0	Radiation - 1 mSv/yr	50
Some Other One-in-a-Million Risks			
Motor vehicle accident - Driving 49 miles		Eating 90 pounds broiled steak (benzopyrene)	
Drinking 22.5 gallons milk (aflatoxin)		Eating 6 pounds peanut butter (aflatoxin)	

Table 13. Biological Effects from Acute Whole Body Exposures

Dose(mSv)	Effect
0-250	No detectable effects.
250-1,000	Slight blood changes with recovery within a few months. Delayed effects possible, but very serious effects very improbable.
1,000-2,000	Nausea and fatigue. Blood changes with delayed recovery.
2,000-3,000	Nausea and vomiting on first day. Latent period up to a few weeks, then malaise, sore throat, diarrhea. Recovery likely within 3 months for healthy individuals.
3,000-6,000	Nausea and vomiting within a few hours. Latent period up to 1 week, then malaise, fever, hemorrhage, loss of weight, sore throat. Death to about 50% of individuals receiving about 3500 mGy (350 rem).
6,000+	Symptoms similar to above, but probable death for 100%

Table 14 . Effects of Skin Irradiation with ∃s or Low-energy X-rays

Dose (mSv)	Effect
2,000-5,000	Reddening of skin (erythema)
20,000	Skin damage (blisters)
30,000	Sever skin damage (ulceration)

F. EXTERNAL RADIATION

1. Gamma Rays

a. Radiation Fields from Gamma-emitters

Most work with gamma-emitters involves the use of 1 mCi (40 MBq) or less. In Table 11, the radiation field at 10 cm (4 inches) from a 1 mCi (37 MBq) unshielded point source is given for some commonly used isotopes. This distance probably represents the closest approach of the hands if appropriate handling tools are used.

Table 15. Gamma Ray Dose Rates in Tissue (mSv/h) at 10 cm from a Point 1 mCi Unshielded Source

Isotope	Major Gamma Ray Energies (MeV)	mSv/h at 10 cm	Isotope	Major Gamma Ray Energies (MeV)	mSv/h at 10 cm
C-11	0.511	0.57	Cu-64	0.511, 1.346	0.11
N-13	0.511	0.57	Zn-65	0.511, 1.116	0.30
0.15	0.511	0.57	Rb-86	1.077	0.05
F-18	0.511	0.57	Mo-99	0.181, 0.740	0.08
Na-22	0.511, 1.275	1.14	Tc-99m	0.141	0.06
Na-24	1.369, 2,754	1.76	In-111	0.171, 0.145	0.20
Cr-51	0.320	0.02	I-125	0.035	0.16
Fe-59	1.099, 1.292	0.60	I-131	0.284, 0.365, 0.637	0.20
Co-56	0.511, 0.847, 1.238	1.33	Cs-134	0.569, 0.605, 0.796	0.81
Co-57	0.014, 0.122, 0.137	0.09	Cs-137	0.662	0.33
Co-58	0.511, 0.811	0.52	Au-198	0.412	0.22
Co-60	1.173, 1.332	1.25	Am-241	0.060	0.02

For radioisotopes not included in Table 11, the following simple approximation can be used:

$$R = 0.5\, E\gamma\,(avg)$$

where R = radiation field in mSv/hr at 10 centimetres from a one millicurie point source

$E\gamma$ (avg) = average gamma-ray energy per disintegration, in MeV.

For example, ^{60}Co decays with the emission of a 1.173 MeV gamma and a 1.332 MeV gamma, both 100% of the time. Using our formula, we would predict:

$$R = 0.5 \times (1.173 + 1.332) = 0.5 \times (2.505) = 1.25 \text{ mSv/hr at 10 cm from 1 mCi.}$$

It may be convenient to know the radiation field at distances other than at 10 cm. For gamma-rays, we can use the "INVERSE SQUARE LAW". The inverse square law simply states that at half the distance, the field increases by four; at one third the distance, the field increased by nine; and at one tenth the distance, the field increased by one hundred.

Mathematically, the inverse square law is given by:

$$R(x) = R(o) \times d_x/d_o)^2$$

where R(x) - radiation field at distance d_x and R(o) = radiation field at distance d_o.

For example, from Table 11, the radiation field at 10 cm from 1 mCi ^{125}I is 0.16 mSv/hr. During iodinations, it is not uncommon to use 2 mCi ^{125}I, and this will often be at a distance of about 1 cm from the fingers. The dose rate from 1 mCi at 1 cm is

$$R(1) = 0.16 \times (10/1)^2 = 0.16 \times 10^2 = 16 \text{ mSv/hr}$$

At 1 cm from 2 mCi, the dose rate would be 2 x 16 mSv/hr = 32 mSv/hr.

From this dose rate, we can now estimate the total dose received. Typically, the ^{125}I is at 1 cm from the fingers for 30-60 seconds. Taking one minute as the exposure time, then

$$\text{Dose} = \text{Dose rate} \times \text{time of exposure} = 32 \text{ mSv/hr} \times 1/60 \text{ hours} = 0.53 \text{ mSv}$$

b. Protection from Gamma-rays

The three basic methods of reducing radiation fields are: **time; distance; and shielding.**

Time: It is obvious that the less time spent in a radiation field, the less the dose will be. As elementary as this principle is, many researchers tend to overlook it. For example, stock solutions and glassware should be prepared as much as possible before working with radioisotopes, and not when the unshielded isotope is in the work area.

Distance: The inverse square law has been discussed and so you should be aware of the role of distance. For example, if a pair of 6" tongs is used to hold a radioactive source rather than a pair of 2" tweezers, the dose is reduced by $(6/2)^2$ or by a factor of 9.

Shielding: Generally, the greater the density of the material, the more effective it is as a gamma-ray shield for a given energy. In addition, the thickness of the chosen material required to reduce the radiation field by a fixed amount depends upon the gamma-ray energy. In Table 12, the thickness of lead required to reduce the radiation field by a factor of twenty is given for some common isotopes.

c. Summary

(1) There is usually a simple relationship between the average gamma-ray energy per disintegration and the radiation field.

(2) The inverse-square law is valid for gamma-rays.

(3) It can be difficult to shield energetic gamma-rays. For example, well over an inch of lead is required to reduce the radiation field from ^{22}Na by a factor of 20.

(4) For the procedures, isotopes, and quantities, and normal working distances used in the research laboratories at CCIW, significant whole body gamma-ray exposures are unlikely. Hand exposures could be significant if insufficient distance is left between the source and the fingers, or insufficient shielding is used, or if the time of exposure is unnecessarily long.

Table 16. Thickness of Lead in cm Required to Reduce a Gamma Ray Radiation Field by a Factor of 20

Isotope	1/20th thickness (cm Pb)	Isotope	1/20th thickness (cm Pb)	Isotope	1/20th thickness (cm Pb)	Isotope	1/20th thickness (cm Pb)
C-11	1.77	Cr-51	0.78	Cu-64	1.85	I-125	0.01
N-13	1.77	Fe-59	4.25	Zn-65	4.06	I-131	1.24
O-15	1.77	Co-56	4.66	Rb-86	4.01	Cs-134	2.74
F-18	1.77	Co-57	0.08	Mo-99	2.57	Cs-137	2.45
Na-22	3.51	Co-58	2.97	Tc-99m	0.11	Au-198	1.29
Na-24	5.71	Co-60	4.41	In-111	0.19	Am-241	0.01

2. Beta Particles

a. Radiation Fields from Beta-emitters

In contrast to gamma-rays, there is no simple relationship between the beta-particle energy and the radiation field from a point unshielded source. Approximate values of the dose rate as function of distance for some commonly used isotopes are given in Table 13. (The commonly used isotopes ^{51}Cr, ^{99m}Tc, and ^{125}I decay without the emission of a beta-particle, although electrons may be emitted from the atom). There are several important points illustrated in Table 13.

(1) The inverse-square law does not apply for low and medium energy beta-emitters. This is of great significance, and can lead to severe exposures if the inverse square law is mistakenly applied. For example, you could measure the beta radiation field at one meter from 1 mCi (37 MBq) ^{131}I, and note that it is 0.04 mSv/hr. Applying the inverse square law, you would deduce that the radiation field would be 4 mSv/hr at 10 cm and 400 mSv/hr at 1 cm. The actual fields are more than a factor of ten greater than this. Therefore, you should always apply the following rule:

NEVER ESTIMATE A BETA RADIATION FIELD USING THE INVERSE-SQUARE LAW. WHENEVER POSSIBLE, MEASURE THE ACTUAL RADIATION FIELD AT THE WORKING DISTANCE.

(2) The beta radiation field at short distances is much greater than the corresponding gamma-ray field for most isotopes that emit both beta-particles and gamma-rays. For example, the beta field from 2 mCi ^{131}I at 10 cm is 61 mSv/hr whereas the gamma-ray field is only 0.20 mSv/hr. This difference arises because we have defined dose as energy deposited per unit weight of material. Beta particles deposit their energy in a relatively short distance in tissue whereas gamma-rays travel much farther. A beam of energetic beta particles hitting an exposed hand may penetrate 1 cm into the tissue. Gamma rays of the same energy would lose only about 2% of their energy while passing through the entire hand. As a result, the betas deposit about 50 times as much energy, and deposit it in less mass, and so the dose (energy per unit mass) is much greater for beta particles than for gamma-rays.

Table 17. Approximate Beta Tissue Dose Rates in mSv/h from a 1 mCi (37 MBq) Unshielded Point Source.

Isotope	Energy (MeV)	Beta Tissue Dose Rate in mSv/h from Unshielded Source				
		0.1 cm	1 cm	10 cm	30 cm	100 cm
C-14	0.156	1,640,000	15,200	11.3	0.0	0.00
S-35	1.167	1,430,000	13,500	13.9	0.0	0.00
P-33, Ca-45	0.25	1,120,000	11,000	42.5	0.3	0.00
Co-60	0.314	972,000	9,630	55.4	1.0	0.00
Fe-59	0.475	831,000	8,290	68.2	3.1	0.01
Na-22	0.545	910,000	9,080	79.2	4.4	0.03
I-131	0.606	683,000	6,820	61.5	4.0	0.04
Cl-36	0.714	650,000	6,500	60.9	4.7	0.08
Na-24	1.389	476,000	4,760	47.2	4.9	0.31
P-32, Rb-86	1.710	393,000	3,930	39.1	4.2	0.33
Y-90	2.270	276,000	2,760	27.7	3.1	0.30

(3) If you need a quick crude rule of thumb, then you could estimate that at one foot from an unshielded point beta source, the dose rate is about 3 mSv/hr per mCi (37 MBq).

DO NOT APPLY THE INVERSE SQUARE LAW TO THIS VALUE.

b. Protection from Beta Particles

The same three factors (time, distance, and shielding) can be used to reduce your exposure when working with β-emitters.

Time: The discussion regarding time as a factor in the section on gamma-rays is equally applicable to β-particles.

Distance: The lack of applicability of the inverse square law has already been discussed. However, the same principle applies and that is to maximize the hand-to-source distance.

Shielding: We have seen that beta-particles are "bad news" because they deposit their energy in a relatively small amount of tissue. If you are an optimist, this is also "good news" since they will also deposit their energy in a relatively small amount of shielding material. This is illustrated in Tables 18 and 19.

These tables illustrate the following points:

(1) Normal laboratory glassware is 1-2 mm thick. For low-energy beta-emitters such as ^{14}C, ^{35}S, and ^{45}Ca this is sufficient to reduce the external radiation fields to zero. As a result, no special handling procedures will normally be required to reduce the external radiation fields for these isotopes.

(2) For energetic beta-emitters, 1 mm glass provides insignificant shielding, and the radiation fields even through 2 mm glass are very significant.

(3) Lucite, plexiglass, or common plastic of at least 1/2" (12.7 mm) thickness is sufficient to completely eliminate the beta radiation field from commonly encountered radioisotopes.

(4) Water is a cheap effective beta shield. If the radioisotope is dissolved in a relatively large volume, the solution itself is acting as a shield. It is good practice to dilute the isotope as soon as possible and as much as possible to take advantage of the shielding value of water.

(5) A dose of 3,000-10,000 mSv produces skin burns from beta radiation. This dose can be obtained by manipulating an unshielded point 1 mCi (40 MBq) source at 1 mm in about 1 minute. This is roughly the dose that you would receive if you held a plastic syringe containing 1 mCi ^{32}P with your fingers on the barrel over the solution. However, at a distance of 10 cm, it would take over a month to accumulate the same exposure from the same source.

(6) Very little lead, less than 1 mm, is required to shield beta particles. A small fraction of the beta energy is converted to X-rays (bremsstrahlung), but this is an insignificant dose compared to the unshielded beta dose. Lead of about 0.8 mm thickness can be obtained from Health Physics. This lead is very pliable, and can be readily shaped to make customized shields.

In this discussion, no mention has been made of tritium (^{3}H). The beta particle from tritium is so weak (0.018 MeV) that it does not penetrate the outer dead layer of skin. It is not possible to receive and external radiation dose from tritium.

c. **<u>Summary</u>**

(1) At distances of less than 1 meter, the radiation field from an unshielded beta source is normally much greater than from a gamma source of the same strength.

(2) The inverse square law does not work well for beta emitters. Always attempt to measure the radiation field at the working distance and never calculate it from the inverse square law.

Table 18. Tissue Dose Rates in mSv/h from an Unshielded 1 mCi Point Source Through 1 mm Air or Glass

Isotope	Energy (MeV)	Dose Rate in mSv/h through		Dose Rate in mSv/h through	
		1 mm Air	2 mm Air	1 mm Glass	2 mm Glass
C-14	0.156	1,600,000	410,000	0	0
S-35	0.167	1,400,000	360,000	0	0
P-33, Ca-45	0.25	1,100,000	280,000	0	0
Co-60	0.314	970,000	240,000	0	0
Fe-59	0.475	830,000	210,000	45	0
Na-22	0.545	910,000	230,000	50	0
I-131	0.606	680,000	170,000	1,400	0
Cl-36	0.714	650,000	160,000	6,000	3
Na-24	1.389	480,000	120,000	170,000	5,700
P-32, Rb-86	1.71	390,000	100,000	260,000	18,000
Y-90	2.27	280,000	70,000	340,000	40,000

Table 19. Maximum Distances Travelled by Beta Particles

Isotope	Energy (MeV)	Maximum Distance Travelled in cm in			
		Air	Water or Polystyrene	Glass	Lead
H-3	0.019	0.5	0.001	0.00	0.000
C-14	0.156	20	0.03	0.01	0.003
S-35	0.167	20	0.03	0.01	0.003
P-33, Ca-45	0.250	50	0.06	0.03	0.005
Co-60	0.314	60	0.08	0.04	0.007
Fe-59	0.475	120	0.15	0.07	0.013
Na-22	0.545	150	0.19	0.09	0.017
I-131	0.606	160	0.21	0.10	0.019
Cl-36	0.714	200	0.26	0.12	0.023
Na-24	1.389	480	0.62	0.28	0.055
P-32, Rb-86	1.710	610	0.79	0.36	0.070
Y-90	2.270	850	1.10	0.50	0.097

(3) Beta particles can be readily shielded.

(4) Extremely large doses can be received at short distances, leading to this fundamental rule:

NEVER HANDLE RADIOACTIVE MATERIAL DIRECTLY WITH YOUR HANDS

At 1 mm, the radiation field will be at least 100 times greater than at 1 cm.

(5) All beta emitters are not equal. Procedures perfectly acceptable for ^{3}H, ^{14}C, ^{35}S, or ^{45}Ca may be extremely hazardous for energetic isotopes such as ^{32}P.

(6) If a syringe is used to extract an isotope whose beta particles can penetrate the syringe wall, then a syringe shield MUST be used.

G. EXTERNAL CONTAMINATION

If radioactive material contaminates the outer layer of skin, then the affected skin can receive a significant dose from relatively minor quantities of activity. This is illustrated in Table 16 for skin contaminated at a level of 1 mCi/cm^2 (37 kBq/cm^2).

Note that although ^{14}C, ^{35}S, and ^{45}Ca do not normally present an external radiation hazard, but they can lead to a significant skin dose through contamination.

Although exercising good technique will minimize the possibilities of external contamination, some contamination is unavoidable. Therefore, disposable gloves and laboratory coats are required when working with radioactive material.

Table 20. Approximate Skin Beta Dose Rates from Surface Contamination of 1 mCi/cm^2

Isotope	Energy (MeV)	mSv/h per mCi/cm^2	Isotope	Energy (MeV)	mSv/h per mCi/cm^2
H-3	0.019	0	Na-22	0.545	800
C-14	0.156	90	I-131	0.606	700
S-35	0.167	100	Cl-36	0.714	700
P-33, Ca-45	0.252	300	Na-24	1.389	1,000
Co-60	0.314	400	P-32, Rb-86	1.710	900
Fe-59	0.475	700	Y-90	2.270	900

At the end of each working day, you should monitor yourself to ensure that no contamination is present. Be sure, in addition to monitoring your hands and feet, to monitor your hair.

H. INTERNAL RADIATION

Radioactive material can enter the body by inhalation, ingestion, or through intact or wounded skin. Once the radioactive material is in the body, it normally cannot be removed simply except by a combination of radioactive decay and normal biological elimination.

1. **Doses from Internal Exposures**

The annual intake required to produce a dose of 1 mSv for some commonly used radioisotopes is given in Table 17. These are the values adopted in 1990.

For the intake of more than one isotope, the requirement is that the sum of the fractional intakes should not exceed 1. For example, if you should ingest 0.6 of the permissible annual intake of ^3H, then only 0.4 of the permissible annual intake of any other isotope would be permissible. Again, remember that the values in Table 17 are limits, not goals, and the ALARA principle should apply for internal exposures as well as external exposures. The values are for the most restrictive compound of the element.

2. **Protection from Internal Radiation**

To prevent the ingestion of a radioisotope, the following rules should be obeyed:

(a) Good personal hygiene should be established to prevent the transfer of contamination from hands to food, cigarettes, pencils, etc., from where it can be transferred to the mouth. The use of disposable gloves is required for this reason.

(b) In a laboratory containing radioactive material, nothing should be placed in the mouth. The obvious hazard is ingesting radioactive solutions while pipetting. The more subtle hazard of mouth-pipetting is that the glassware may be externally contaminated. This hazard will exist even if the material pipetted is non-radioactive.

(c) **There shall be no eating, drinking, or smoking in a laboratory area containing radioactive material.**

To prevent the inhalation of radioactive material:

(a) When performing work that may produce airborne contamination (e.g. boiling, evaporating, oxidizing), work shall be conducted in a fume hood.

(b) A glove box should be used for such work involving dry radioactive powdered material

(c) Spills involving radioactive material should be cleaned up as soon as possible before the material has the opportunity to dry and become airborne.

All spills should be reported immediately to the RSO (Radiation Safety Officer). To protect against absorption of radioactive material through the skin, any cut, abrasion, or wound must be adequately protected. Even through intact skin, tritium oxide or iodine as a vapour or in solution in an unbound form (e.g., iodide) can be adsorbed.

I. SPILLS

When working with radioactive material, good technique will minimize the number of spills. However, spill is inevitable even with good technique. When the spill occurs, the following procedures should be followed:

(1) Inform all the personnel in the room and delineate the area of the spill to eliminate traffic through the contaminated area.

(2) Inform the RSO immediately.

(3) In the event of a dry spill, wet absorbent paper should be placed over the affected area. Dry absorbent paper should be placed over a wet spill. The papers should be placed in the radioactive waste container and the area monitored.

(4) Decontamination should be carried out until the area is free of contamination. Cleaning should always be done inwards toward the center of the spill. Areas of lesser contamination to areas of lower contamination. Gloves should be worn and care taken to prevent contamination of the skin or ingestion or inhalation of the radioactive material.

(5) Before resuming work, conduct a survey and determine if the contamination has been removed. In addition, the personnel involved in the cleanup must be monitored to ensure that they have not become contaminated.

J. RADIATION DETECTION INSTRUMENTS

Since we cannot detect ionizing radiations with our senses, special instrumentation must be used. There are various types of instruments available, and it is absolutely vital to ensure that the instrument used will actually detect the radiation of interest. For example, ^{14}C cannot be detected with a standard Geiger tube; an end-window tube must be used. It is also important that the readings be interpreted properly.

Table 21 . Characteristics of Some Common Instruments

Instrument	Radiation Detected	Remarks
End Window GM	β,γ ›20 keV	Fragile window
GM (Thin Wall-30 mg/cm^2	β ›200 keV, γ ›40 keV	Note for ^{14}C or ^{35}S or ^{125}I
Ionization Chambers	β›20 keV, γ ›20 keV	Relatively low ∃ sensitivity
Scintillation	γ ›10 keV	Good for ^{125}I

DO NOT USE A SURVEY INSTRUMENT WITHOUT PROPER INSTRUCTION

To ensure that the instrument is suitable for the intended purpose and to ensure that the readings are interpreted correctly, refer to the manufacturer's manual. None of the above instruments will detect tritium.

K. RULES AND PROCEDURES

1. General Rules for All Radioisotope Users

The following rules have been formulated to reduce your radiation exposure and <u>must</u> be obeyed since they represent the policy of both the CCIW and the CNSC.

These rules will assist in reducing internal exposures:

(a) There shall be no smoking, eating, drinking, or storage of food in a laboratory containing radioactive material.

(b) Do not mouth pipette radioactive solutions.

(c) When performing work that might produce airborne contamination (e.g. boiling, grinding, oxidizing, iodinations) work must be conducted in a fume hood.

(d) A glove box should be used for work involving dry powdered radioactive material.

(e) Do not work with radioactive material if you have open cuts or abrasions.

These rules will assist in reducing your external exposures:

(f) Whenever possible, perform a trial experiment using stable or low activity material to establish the adequacy of the procedures and equipment.

(g) Never handle radioactive material directly with your hands.

(h) Measure the external radiation fields, using suitable instruments during your initial experiment.

These rules will assist in reducing personal contamination:

(i) Use protective gloves and clothing whenever hand or clothing contamination is possible.

(j) After working with unsealed radioactive material:

  - (i) hands shall be washed before leaving the laboratory;
  - (ii) clothes, shoes and hands monitored for contamination.

To reduce laboratory contamination:

(k) Use disposable absorbent liners on trays or bench surfaces.

(l) Objects and equipment used for work with radioactive material should not be used for other purposes and should be monitored before removal from laboratory.

(m) Immediately inform the RSO if there is a spill of radioactive material.

2. **Special Rules for P-32 Users**

Because of the great potential for skin exposures from ^{32}P, it is recommended that your initial experiment with ^{32}P be monitored by the RSO if you use more than 0.25 mCi (10 MBq). At this time, you will see the radiation fields monitored at actual working distances and so hopefully, will appreciate the potential hazards. Also, your procedures will be reviewed and means of reducing your exposures brought to your attention. If necessary, additional shielding will be recommended and subsequent experiments monitored until a satisfactory protocol is established.

3. Procedures for Radioiodine Users

For those workers using significant quantities of unbound radioiodines as open sources, the following CNSC Licence conditions apply:

Every person who:

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

i) 5 MBq in an open room;

ii) 50 MBq in a fume hood;

iii) 500 MBq in a glove box

iv) any other quantity in other containment approved in writing by the Commission or a person authorized by the Commission; or

b) is involved in a spill of greater than 5 MBq of volatile I-125 or I-131;

c) or on whom I-125 or I-131 external contamination is detected; and shall. undergo thyroid screening within 5 days following the exposure to I-125 or I-131.

Thyroid Screening

Screening for internal I-125 and I-131 shall be performed using

a) direct measurement of the thyroid with an instrument that can detect 1 kBq of I-125 or I-131; or

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

Thyroid Bioassay

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

Failure to comply with CNSC licence requirements can lead to suspension of radioiodine use.

L. USEFUL REMINDERS AND HINTS

(a) The radioactive work area should contain all appropriate signs.

(b) Non-radioactive areas must be clearly defined and signed.

(c) Refrigerators containing radioactive material must **NOT** contain foodstuffs.

(d) The work area should be covered with absorbent paper.

(e) When conducting an experiment, it is often useful to have a small waste container adjacent to the work area. This can be easily shielded and then emptied into the main waste container at the end of the experiment. This procedure minimizes traffic and reduces the probability of spreading contamination.

(f) Have long tweezers or tongs handy.

(g) When working with large volumes of solution (say 100 ml or more), conduct the work in a tray.

(h) Have shielding apparatus handy and use it.

(i) Areas in which radioactive stock solutions are stored should be clearly labelled and the radiation field posted.

(j) Use lab coats. Check frequently for contamination, particularly sleeves and pockets. do not wear these lab coats into eating areas such as cafeterias and lounges.

(k) An inventory of radioactive material in the laboratory must be maintained.

(l) The following must be prominently displayed in the laboratory:

- the permit to use radioactive material
- a copy of the CNSC regulations
- spill emergency procedures
- ^{32}P posters if this isotope is used.

APPENDIX A

Table 1 . Maximum Annual Dose Limits in mSv*

Item	Column 1	Column 2	Column 3	Column 4
	Organ or tissue	Person	Period	Equivalent Dose (mSv)
1.	Lens of an eye	(a) Nuclear energy worker	One-year dosimetry period	150
		(b) Any other person	One calendar year	15
2.	Skin	(a) Nuclear energy worker	One-year dosimetry Period	500
		(b) Any other person	One calendar year	50
3.	Hands and feet	(a) Nuclear energy worker	One-year dosimetry period	500
		(b) Any other person	One calendar year	50

*Dose in mrem = dose in mSv x 100

Table 2 . Radiation Weighting Factors

Type and Energy Range		Radiation Weighting Factor
Photons, All Energies		1
Electrons, All Energies		1
Neutrons, Energy	‹ 10 keV	5
	10 keV to 100 keV	10
	› 100 keV to 2 MeV	20
	› 2 MeV to 20 MeV	10
	› 20 MeV	5
Alpha Particles		20

Table 3 . Tissue Weighting Factors

Tissue or Organ	Weighting Factor
Gonads	0.20
Red Bone Marrow, Colon, Lung, Stomach	0.12
Bladder, Breast, Liver, Oesophagus, Thyroid	0.05
Skin, Bone Surface	0.01
Remainder	0.05

APPENDIX B

<u>Permissible Quantities of Isotopes in Laboratories</u>

Type of Laboratory	Permissible Quantity of Radioactive Material Expressed in ALIs Handled as an Unsealed Source on Benchtop
Basic	‹ 5 ALI
Intermediate	50 ALI
High	› 50 ALI

APPENDIX C

<u>EQ - Exemption Quantities, and ALI - Annual Limit on Intake for select Radionuclides</u>

Isotope	EQ		ALI		Isotope	EQ		ALI	
	uCi	**kBq**	**uCi**	**kBq**	**kBq**	**uCi**	**kBq**	**uCi**	**kBq**
Am-241	**0.03**	**1**	**3**	**100**	**I-131**	**0.3**	**10**	**27**	**910**
C-14	**2700**	**10,000**	**1000**	**34000**	**K-42**	**0.3**	**10**	**600**	**22000**
Ca-45	**27**	**1000**	**700**	**26000**	**Mn-56**	**0.03**	**1**	**2000**	**80000**
Co-57	**2.7**	**100**	**27000**	**95000**	**Na-24**	**0.3**	**10**	**1400**	**47000**
Cr-51	**270**	**1000**	**16000**	**530000**	**P-32**	**0.3**	**10**	**200**	**8300**
Fe-59	**2.7**	**100**	**270**	**11000**	**P-33**	**270**	**1000**	**2000**	**83000**
H-3	**27000**	**100000**	**270000**	**100000**	**Rb-86**	**0.3**	**10**	**190**	**7100**
Ag-110m	**0.3**	**10**	**150**	**7100**	**Tc-99m**	**2700**	**10,000**	**24000**	**910000**
I-125	**270**	**1000**	**30**	**1300**	**In-111**	**2.7**	**100**	**1850**	**69000**

PART 2

ORGANIZATION OF RADIATION MONITORING ACTIVITIES

I. CCIW SAFETY AND HEALTH FORUM (SHF)

Preamble

The SHF represents all levels of management, unions, and security, and develops CCIW radiation safety policy to:

(i) ensure compliance with radiation protection regulations promulgated by the Canadian Nuclear Safety Commission;

(ii) establish and continually review CCIW radiation protection program; and

(iii) to produce and continually review CCIW Radiation Protection Manual.

Authority

The SHF receives its authority from CCIW Management and conveys its recommendations to the Executive Director, National Water Research Institute.

Responsibilities

The SHF is charged with the following responsibilities:

(i) review and authorize in conjunction with the RSO all uses and locations of use of radioactive materials (i.e., GUP's and RLP's - User & Lab Permits), assist RSO in maintaining communications with individual radioisotope users.

(ii) review internal inspection reports of radioisotope users and locations, the RSO's reports all incidents or unusual occurrences involving radioactive material to determine if appropriate and effective radiation safety procedures are being followed, review incidents of non-compliance and if necessary institute remedial action such as suspension of radioisotope use permit etc.

(iii) periodically review all aspects of radiation handling procedures and recommend modifications, where necessary, provide consultation on problems dealing with radioactive materials and radiation hazards.

(iv) arrange for educational seminars, etc. with the view of providing all radioisotope users, supervisors, etc. with the information necessary to appreciate the hazards associated with radioisotope work,

(v) review the RSO's summary report of the occupational radiation exposure records of all personnel monitored and determine if these are being kept as low as reasonably achievable.

(vi) monitor all radiation safety issues to ensure they are appropriately addressed by management and advise senior management of any deficiencies in resources necessary to maintain an adequate radiation safety program

Membership

The SHF draws its membership from all radioisotope user organizations located at CCIW as follows:

Advisors:

B. Malseed	CCIW/CFSSO	K. Strohack	Health Canada
C. McKay-Gordon	HRB-OR	J. FitzGerald	AEMRB

Changes to membership may be made to reflect the current needs. J. FitzGerald, AERB (NWRI), acts as the CCIW Radiation Safety Officer (RSO).

Responsibilities of the RSO

The RSO is charged with the following specific responsibilities

(I) advise CCIW Management on radioactivity related matters.

(II) maintain contact with the CNSC. The RSO will advise members of the SHFor other individuals, as appropriate, of any new relevant developments and licensing requirements. The RSO will assist CNSC in their annual or any other inspections of the CCIW laboratories, including those aboard research vessels, by making available all records, etc.,

(iii) prepare radiation safety issues for presentation at meetings,

(iv) prepare an annual report for the consolidated licence for onward submission to the CNSC.

(v) ensure smooth running of the thermoluminescent dosimetry program for CCIW employees by (a) maintaining regular contact with the Radiation Protection Bureau, Health and Welfare Canada, and (b) ascertaining proper functioning of internal distribution and collection system. The RSO will also notify an individual and the study leader as soon as an abnormal dose is recorded on the dosimeter,

(vi) issue the laboratory and group user permits (Appendices I and II) and evaluate requests for use of radioisotopes aboard research vessels (Appendix III) and by non-CCIW staff (Appendix IV),

(vii) maintain radioisotope purchase and inventory records (2.VI) and completed inventory sheets (Appendix V),

(viii) arrange for the storage and handling of radioisotopes (at levels higher than those permitted in a basic level laboratory) in the intermediate level laboratory,

(ix) coordinate regular monitoring of laboratories and radioactive waste disposal activities and attend to emergencies with the assistance of members of the SHF. The RSO will also supervise the decommissioning of radioisotope use laboratories and the transportation of radioactive material,

(x) coordinate EC detector radiation safety program (2.XIII) with the assistance of the members of the SHF.

II. DESIGNATED RADIOISOTOPE LABORATORY PERMIT

Laboratories are designated as Basic or Intermediate, according to the level of work to be conducted. For purposes of designation radioactive quantities are measured in units called ALIs (Annual Limit on Intake) to reflect radiological risk. ALIs for radioisotopes can be found in Table 1.

- A basic level laboratory allows for the use of up to 5 ALIs as an unsealed or open source of radioactivity. Higher level work must be conducted in an intermediate level laboratory.
- An intermediate level laboratory allows up to 50 ALIs or 10 times the quantity of a basic level lab.

Each radioisotope use laboratory, including those aboard research vessels, is considered a 'basic' laboratory. Limits are placed on the levels of radioisotopes stored in all laboratories (Appendix I). In compliance with the CNSC Rules and Regulations, each such laboratory will display the RLP (Appendix I) and the "Rules for Working with Radioisotopes in a Basic Laboratory". A copy of the CNSC licence will be prominently displayed outside the intermediate level laboratory. A copy of the licence will also be kept in each basic laboratory. All designated laboratories, when in use, will be monitored.

The limits specified in the RLP correspond to 5 "ALIs" (see 2.X, Table I) and are applicable to all locations other than the intermediate level laboratory. This factor of ten is recommended by Health and Welfare Canada for normal wet chemical operations with radionuclides in a well-designed chemical laboratory. Because of practical reasons the limits have been substantially raised for ^{3}H and ^{14}C (both weak β -emitters) and by a factor of ten for ^{32}P (see also 2.VII.C)

III. RADIOISOTOPE GROUP USER PERMIT

In addition to the Designated Radioisotope Laboratory Permit (which identifies a radioisotope use area), permits are issued to each group which uses the radionuclides. Usually the GUP (Appendix II) is issued to the study leader as the responsible member of the group. All personnel who use radionuclides in CCIW are referred to as "users". The GUP authorizes a group to use specific radionuclides in stated areas. Each time the group wants to use radioisotopes aboard research vessels, proper notification must be given. Study leaders must be aware of the hazards and the responsibilities associated with using radioisotopes. They must ensure that all users are properly trained and experienced, and have read and understood this manual. All users must observe all the necessary safety procedures. The immediate supervisor of each user is responsible for the safety of his (her) subordinate. A copy of the GUP will be kept on file with the RSO.

IV. RESEARCH VESSELS

All radioisotope users must obtain prior permission from the RSO to use radioisotopes aboard CCIW research vessels. The study leader must complete the form titled "Notice of Intent to Use Radioisotopes Aboard Research Vessels" (Appendix III) at least two weeks before the scheduled cruise date. The RSO would sign the form following discussion of safety aspects with the originator. The completed and signed form shall then be given to the Technical Operations Division Officer-In-Charge of the cruise who also maintains the radiation monitoring records aboard R/Vs. A copy will be kept on record with the RSO.

The experimenter(s) should be prepared to remove any accidental spills and should carry an adequate supply of decontaminating agent, papers, sponges, brooms, etc. Any such cleanup operation is the sole responsibility of the experimenter(s).

All experiments will be conducted in accordance with the CCIW Radiation Protection Manual and the "Rules for Working with Radioisotopes in a Basic Laboratory" posted on each ship. The experimenter(s) will, in addition, provide disposable shoe covers to others working in the same area on a project different from that involving radioisotopes, and will inform them of the presence of radioactive materials.

Plastic labware should be used aboard R/Vs to minimize accidental spills, etc. To further avoid spills on the floor, the experimenter should ensure that the wooden laboratory benches are lipped all around borders. A temporary lip is readily constructed using commonly available hard plastic strips and duct tape. The bench top should be covered with a plastic liner and disposable absorbent paper. Radioisotope work on trailers and at field sites should be conducted in accordance with rules outlined in this manual.

V. NON-CCIW RADIOISOTOPE USERS

On occasion, researchers affiliated with external agencies collaborate with CCIW staff on radioisotope work. In such instances, the collaborating CCIW staff are required to seek approval from the RSO well in advance of the intended use of radioisotopes by non-CCIW personnel by filling out the form titled "Notice of Intended Use of Radioisotopes by Non-CCIW Staff" (Appendix IV). A copy of the completed form will be kept by the RSO. Granting of such permission, however, does not absolve the collaborating CCIW staff of his (her) responsibilities which are deemed to be equivalent to those of a Study Leader. In addition, the CCIW collaborator would ensure that the external staff do not import any radioisotopes into the CCIW complex without prior permission from the CNSC.

Note: Please refer to the attached protocol titled "Collaboratorive Radioisotope Work Requirements" forming part of Appendix IV.

VI. PURCHASE OF RADIOISOTOPES AND INVENTORY

All radioisotope users must notify the RSO and obtain approval prior to procuring any radioactive material (including electron capture detectors and any other sealed or electrodeposited radioactive sources). The RSO, or designated alternate, will place the CNSC licence number on all 1851s or local purchase orders before the requisition is given to the Administrative Officer. At the same time, the RSO will initiate the Radioisotope Inventory sheet (Appendix V) for the said purchase. This inventory sheet is required for any possible future audit by the CNSC. The inventory sheet will be stored in R114C until the shipment is received. All radionuclide shipments received at the warehouse (or central registry) will be forwarded to the RSO, whereupon pertinent data will be entered into a permanent record book and the inventory sheet. The purchaser will then be notified of the shipment's arrival and will be issued, along with the radionuclide, the inventory sheet to record withdrawals of materials, disposal, etc. The RSO will examine the inventory sheets on an annual basis until the shipment is finished, at which time the completed inventory sheet will be returned to the RSO. It is the responsibility of the purchaser to comply with this regulation and to ensure that any unused radioactive materials are properly disposed of. The RSO (Ext. 4779) and purchaser will have responsibility for maintaining the records.

VII. RULES FOR WORKING WITH RADIOISOTOPES

The following rules have been formulated to reduce your radiation exposure and must be obeyed since they reflect the policy of the CNSC and the CCIW Management. Any other conditions specified on the CNSC licence will also apply.

A. Rules for Basic Laboratories Including Those Aboard Research Vessels and Trailers, etc.

General

1. Each area and room where radioisotopes are stored must be posted with a "Radioactive Materials" sign. Proper signs are available from the RSO.
2. Careful organization and the practice of good techniques and personal hygiene will minimize any risks to health and safety.
3. Be aware of the hazards. Project supervisors are responsible for providing instruction, facilities and equipment.
4. Eating, drinking and smoking are forbidden in radioisotope laboratories.
5. Personal belongings, not required for work, should not be brought into the lab as they may become contaminated.
6. Inform other workers in the area that you are working with a radioactive material. A TLD plaque should be worn by all for experiments involving all isotopes other than low-energy beta-emitters such as ^{14}C and ^{3}H. Additional plaques are available through your representative on the RSC.
7. Direct contact with radioactive materials must be avoided through the use of lab coats and protective gloves.
8. Before leaving the radioisotope laboratory, hands should be washed. Hands, clothes and shoes should then be monitored. A survey meter is appropriate for this purpose.

Work Procedures

9. All procedures should be preplanned and first executed on a "dry-run".
10. Pipetting of solutions by mouth is forbidden. Pipetting devices should be used.
11. Sources should be handled in such a way that the radiation dose incurred is minimized. This is accomplished by the use of long-handled tools and shielding if necessary.

12. Work should be done in a fume hood if the material is volatile or if it may spray or splatter.
13. Work with dry, dusty, radioactive material should be done in a glove box.
14. Disposable absorbent paper should be used on benches and in trays to prevent contamination of work surfaces.
15. Laboratory glassware and equipment should be decontaminated after use and should not be removed from the radioisotope laboratory without being checked for contamination.
16. Radiation fields and contamination levels in the lab should be monitored frequently, especially before and after the experiment. Radiation fields should be kept below 0.25 mrem/hr (2.5 μSv/hr) and contamination in designated radioisotope use areas should be controlled to less than the allowable level for the class of isotope in use. See table below.

Accidental Spills, etc.

17. Immediately report all spills and incidents of suspected personal contamination or exposure to your study leader/supervisor, your representative on the RSC, and/or to the RSO (Ext. 4779) Minor surface contamination, however, should be handled immediately by the experimenter by instituting standard decontamination procedure.

Storage

18. All containers and samples of radioactive material, including wastes, should be labelled and stored in properly designated locations. Radiation levels outside the storage facility should not exceed 0.25 mrem/hr (2.5 μSv/hr).

B. Rules for Intermediate Level Laboratory

General

1. The radioisotope laboratory shall be kept locked at all times when not being used.
2. No person shall enter the radioisotope laboratory unless he is authorized to be there.
3. EATING, DRINKING or SMOKING shall not be permitted inside the radioisotope laboratory. All pertinent areas will be posted with "Radioactive Materials" signs.

Visitors

4. Visitors shall not be allowed into the radioisotope laboratory without specific permission from the person in charge.
5. Visitors shall wear a laboratory coat and protective foot covering while in the radioisotope laboratory.
6. Visitors should be provided with a TLD plaque while in the radioisotope laboratory and a record of the readings shall be maintained.
7. Visitors shall be monitored for external contamination as they leave the radioisotope laboratory.

Safety Precautions

8. Precautions should be taken to avoid skin punctures or cuts, especially when the more toxic radionuclides are being handled. Anyone who has an open skin wound below the wrist (protected by a bandage or not) should not work with radioactive materials.
9. The use of containers, glassware, etc., with cutting edges should be avoided.
10. Direct physical contact with radioactive materials should be avoided through the use of special lab coats, protective gloves and protective foot coverings. These should be distinctively marked and must not be worn in ordinary laboratories.
11. No work with radioisotopes shall be undertaken unless a suitable radiation monitor is available in the laboratory.
12. TLD plaques shall be worn by all persons working in the radioisotope laboratory.

13. Before leaving the radioisotope laboratory hands should be washed thoroughly. Special attention should be given to the nails, and between the fingers.
14. Hands, clothes and shoes shall be monitored before leaving the radioisotope laboratory.

Work Procedures

15. Work with unsealed radioactive isotopes should be done in a fume hood.
16. Work involving spray, fume or gas evolutions must be done in a fume hood.
17. Work with dry radioactive powders should be done in a glove box.
18. Work with radioactive substances should be done on trays protected with disposable absorbent liners.
19. Disposable paper towels and wipers, and special marked containers for their disposal if contaminated shall be provided.
20. Pipetting of solutions and glass blowing shall not be done by mouth in the radioisotope laboratory
21. Equipment shall not be removed from the fume hood to any other part of the radioisotope laboratory without first being checked for contamination. Equipment and chemicals shall not be removed from the radioisotope laboratory without first being checked and found free from contamination. Glassware used for radioactive work must not be used for other purposes.
22. Floors and working surfaces should be swipe-checked daily when the laboratory is in use.
23. When work is completed, each person shall clean and/or isolate contaminated supplies and equipment. Each person shall also monitor and decontaminate trays, floor and working surfaces.
24. The radioisotope laboratory shall be "damp-cleaned" and monitored at least once a month or more frequently while in use.

Storage and Waste Disposal

25. All radioactive substances shall be placed in containers bearing the radiation warning symbol. Each container should be marked to indicate the kind and quantity of radioactive material.
26. When not in use, the containers shall be stored in a safe place provided with adequate shielding (the radiation level at the outer surface should not exceed 2.5 mrem/hr, or 25 μSv/hr).
27. Disposal of all radioactive wastes shall be carried out only according to specific instructions from the person in charge.

Accidents

28. Procedures to be followed in case of emergencies should be prepared and studied by all concerned. Copies of the procedures should be posted in the laboratory.
29. Following any spill or accident involving radioactive material, immediate action shall be taken to limit the spread of contamination. Access to the contaminated area by unauthorized persons shall be prohibited. The person in charge shall be informed as soon as possible.

C. Special Rule for ^{32}P Users

The radiation dose rates from ^{32}P, which is often purchased as a solution with high specific activity, are quite high even when it is still in its ampoule. A spill of even a few microlitres of such a solution delivers a significant dose to the cells in the basal layer of the skin. For example, 1 MBq/cm^2 results in a radiation dose rate of 2.4 Sv/hr (1 μCi/cm^2 results in approximately 90 Rem/hr). Some of the ^{32}P contamination can be absorbed through the skin, and hence enter the blood stream. This will result in increased radiation dose to bone tissues since phosphorous is preferentially deposited in bone.

Because of the great potential for skin exposures for users of ^{32}P, it is a requirement that your experiments involving ^{32}P be discussed with the RSO before procuring the radioisotope. It is recommended that all efforts should be made to substitute ^{32}P with ^{33}P. The latter radioisotope has the advantage of a longer half-life and lower energy (than ^{32}P) but is somewhat more expensive.

VIII. PERSONNEL MONITORING

The RSO, in consultation with the respective member of the RSC, determines during the permit evaluation the need for thermoluminescent dosimeter (TLD) plaques. Adequate supplies of these plaques are procured by the RSO from the Radiation Protection Bureau (RPB), Health and Welfare Canada. Plaques are distributed around the middle of February, May, August and November. The RSO (Ext. 4779) distributes these plaques to the members of the RSC who, in turn, collect the plaques for the previous quarter and give new ones to the study leaders/users. All used plaques must be returned by the due date to your member of the RSC who passes these on to the RSO for onward remittal to the RPB. You must hand your plaque in earlier if you will be away on vacation during the normal collection period. (The RPB requires an explanation from the RSO for any delays involved. This results in unnecessary additional work and is thus a waste of time for the people involved.) The cost of any lost or damaged plaque will be met by the study leader concerned. It is the responsibility of the study leader to ascertain that all persons, including term employees, students, etc., required to wear a TLD do so.

The RPB provides the RSO with the information regarding radiation dose received by users on an individual basis. The RSO maintains all such records and will notify an individual and the study leader concerned as soon as an abnormal dose is indicated.

IX. WEEKLY MONITORING OF LABORATORIES

Radioactive contamination must be monitored by direct or indirect means to ensure that the allowable limits are not exceeded.

Direct monitoring of working surfaces, apparatus, and staff can be performed using appropriate contamination monitors that have been calibrated for the isotope in use.

Indirect monitoring by means of a wipe or swab of the area of interest which is counted in a liquid scintillation counter may be necessary to detect low energy beta emitters such as H-3.

A weekly radiation survey of all laboratories (when in use), including swipe tests at selected spots, will be performed by user groups (Appendix VI). This regulation is also applicable to laboratories aboard research vessels where surveys will be performed by TOD staff as applicable. The user groups will maintain original records which will be made available to the CNSC for inspection when required and to the responsible member of the RSC on a quarterly basis. The CNSC licence stipulates that the levels in the radioisotope use areas should not exceed the allowable levels for the particular class of isotope in use. Any discrepancies above this level should be immediately corrected. Any persistent discrepancies should be discussed with the responsible member of the RSC and, if the need be, with the RSO. Each user group is expected to have its own monitor which should be calibrated periodically. The calibration is easily checked by using the standard radioactive source supplied by the manufacturer. Additional calibration checks are normally available with the manufacturer. Some other commercial outfits can also provide calibration checks. Information on these is available from the RSO (Ext. 4779).

Users of unsealed sources of nuclear substances must ensure by monitoring at least weekly that non-fixed contamination does not exceed the levels shown in Table 1.

Table 1. Allowable Levels of Non-fixed Contamination

Class of Radionuclide	All areas, rooms, or enclosures where unsealed nuclear substances are used or stored	All other areas
Class A	3 Bq/cm^2	0.3 Bq/cm^2
Class B	30 Bq/cm^2	3 Bq/cm^2
Class C	300 Bq/cm^2	30 Bq/cm^2

X. RADIOACTIVE WASTE DISPOSAL

Disposal of all radioactive wastes must be in accordance with the CNSC regulations. The following permitted options require no special arrangements:

(a) For materials readily soluble and dispersible in water the annual limit given in Table 2 below must not be exceeded. See RSO for disposal limits assigned to each permit group.

(b) To the atmosphere provided that the resulting concentration in air at the point of release is less than the concentration stated in Table 2.

(c) Via normal garbage provided that the activity concentration is less than the quantities per kilogram stated in Table 2.

Disposal of all other types of radioactive wastes (sealed sources, unused radiochemicals, etc.) and wastes not conforming to above options should be arranged with the Atomic Energy of Canada Limited.

Details of procedures to be followed for disposal through the AECL are available from the RSO (Ext. 4779)

The radwastes should be segregated and contained as follows:

Disposal Limits Allowed by Licence Conditions

Table 2. Disposal

Column 1 Nuclear Substance	Column 2 (a) Limits solids to municipal garbage system Quantity per kg	Column 3 (b) Limits liquids (water soluble) to municipal sewer system (quantity per year)	Column 4 (c) Limits gases to atmosphere (quantity per cubic metre)
Ar-41			0.037 kBq
C-14	3.7 MBq	10,000 MBq	
Cr-51	3.7 Mbq	100 MBq	
Co-57	0.37 MBq	1000 MBq	
Co-58	0.37 MBq	100 MBq	
Ga-67	0.037 MBq	100 MBq	
H-3	37 MBq	1 000 000 MBq	37 kBq
In-111	0.037 MBq	100 MBq	

Liquid Wastes

Contaminated organic solvents and scintillation counter fluids should be emptied into an appropriately labelled safety container, and must not be disposed of via the sewer. If the waste is less than 0.01 EQ/L, the container should be emptied into a larger container located in the warehouse. Commonly-used plastic or glass scintillation vials need not be emptied into the larger container as the waste disposal company will accept these provided the amount is less than 1 EQ/L. All persons depositing radioactive liquid scintillator waste in the warehouse must submit the completed form titled "Disposal of Liquid Scintillator Waste" (Appendix VII) to Materiel Management. All other aqueous wastes may be disposed of via the sewer provided the amount is less than the quantity shown in Column 3 of Disposal Table 3, and provided no other hazard exists.

Solid Wastes

Contaminated combustible dry waste (paper, gloves, etc.) should be collected in an appropriately labelled container lined with a polyethylene bag. Non-combustible lab waste (glass, empty scintillation vials, etc.) should be collected in an appropriately labelled container lined with a heavy polyethylene bag. Sharp objects (syringes, etc.) should first be placed in protective containers. If this material contains less activity per kg than the values given in Column 2 then it may be disposed of as normal waste.

Waste containing ^{32}P should be collected separately in an appropriately labelled container lined with a heavy polyethylene bag which, when full, can be labelled, dated and stored until such time as the ^{32}P becomes virtually inactive prior to disposal as radwaste

Non-radioactive wastes should not be disposed of in radwaste containers. It is the responsibility of the study leader to ensure that all radwaste is disposed of in compliance with CNSC rules and regulations.

XI. EMERGENCY PROCEDURES

A radiation emergency occurs when a set or circumstances result in hazardous radiation levels, hazardous concentrations of airborne radioisotopes, or gross contamination of property. Examples of radiation emergencies and actions to be taken are:

1. Personnel contamination

   a) Remove contaminated clothing.
   b) Wash contaminated skin with mild soap and water. Be especially thorough in flushing out wounds. Do not use abrasives.
   c) Call the RSO (Ext. 4779).

2. Spill of isotope where radioisotope does not become airborne

   a) Wipe up with absorbent paper with a blotting action so as not to spread contamination.
   b) Dispose of contaminated paper in radioactive waste container.
   c) Contact the RSO.

3. Volatilization of liquid or dispersal of solid radioisotope outside a ventilated enclosure

   a) If possible, keep contamination localized by closing doors and restricting access to area.
   b) Leave the area. (Remove shoes if you suspect contamination and do not touch anything unnecessarily.)
   c) Contact the RSO.

4. Fire in the radioisotope area

   a) Treat fire in normal manner.
   b) Call your organization's safety officer as soon as is practical and the RSO.

ALWAYS USE COMMON SENSE IN HANDLING RADIATION EMERGENCIES, AND CALL THE RSO AS SOON AS PRACTICAL. DO NOT TRACK OR OTHERWISE PERMIT RADIOISOTOPES TO BE SPREAD INTO CLEAN AREAS.

NOTE: Although we do not foresee any possibility of severe personal contamination through inhalation or absorption of radioactive materials through skin, conceivably such a situation con occur. In some instances, it is a standard practice to analyze blood and/or urine samples, etc. from the affected individuals for radioactivity. Your study leader, in consultation with the RSO, will arrange for the procurement and analyses of body fluid samples in cases where severe internal contamination is suspected. CCIW does not have its own bioassay facilities; however, tests are readily conducted at the McMaster University Health Centre (which should be contacted only through the RSO).

All body fluids are analyzed with certain precautions in mind. The Health Centre staff will apprise you of exact precautions to be followed. The importance of these precautions is evident when one considers the case of a suspected internal contamination with ^3H - a radioisotope in frequent use at CCIW. After ^3H is inhaled or absorbed through the skin, it is carried to all parts of the body by the blood. It distributes itself equally among all body fluids such as blood, urine, sweat or saliva. Any of these fluids can be analyzed as it is easy to sample. The biological half-life of ^3H is ten days. The maximum permissible body burden is 2 mCi (74 MBq) or 50 uCi/L of urine (1.85 MBq/L). The dose commitment from 1uCi (37 kBq) is 0.10 mrem (1 uSv). Three precautions are required to obtain a urine sample that is truly representative of the concentration of tritium in body fluids:

1. After an exposure it takes about two hours for tritium in urine to reach the same concentration as exists in other body fluids. A sample given one-half hour after exposure may only indicate about 50% as much ^3H as one taken two hours later. A sample given one hour after exposure may indicate about 75% of the true value. If exposed late in the work day, one should give a urine sample before leaving work an another the next day.
2. Two hours after exposure, ^3H concentration steadily decreases as it is eliminated from the body with an effective half-life of ten days. Hence, one should not wait too long. before giving a urine sample A sample given one day after exposure indicates about 93% of initial concentration, and one given four days after will indicate only about 75%.
3. The bladder should be emptied after an exposure, before giving the first sample. This is especially important if the bladder is almost full at the time of exposure. Otherwise, the newly formed urine will be diluted with tritium-free urine in the bladder, and the indicated concentration will be lower than the concentration in other body fluids.

XII. DECOMMISSIONING OF RADIOISOTOPE USE AREAS

When any radioisotope use area is decommissioned, all nuclear substances and radiation devices must be removed, and after radiation surveys have shown that non-fixed contamination is below the values listed in Table 3, all radiation warning signs must be removed or defaced. When decommissioning is complete the contact person (on the Designated Radioisotope Laboratory Permit) will then notify the RSO, in writing, of this change and will provide the area monitoring results.

Table 3. Limits for non-fixed radioactive contamination for decommissioning purposes

Class of Radionuclide	Acceptable Decommissioning Level
Class A	< 0.3 Bq/cm^2
Class B	< 3 Bq/cm^2
Class C	30 Bq/cm^2

The ultimate release of any area, room, or enclosure containing fixed contamination is approved in writing by the Commission, or person authorized by the Commission.

XIII. ELECTRON CAPTURE DETECTOR RADIATION SAFETY

The radioactive deposit of ^{63}Ni inside EC detectors sometimes corrodes. When in operation, a corroded detector deposits ^{63}Ni-labelled particulate material on the outside surfaces of the detector and chromatograph unit. This contamination may also spread from the cell on to the chromatograph column or the oven floor if there is no column in the instrument. For these reasons, the CNSC requires all EC detectors containing ^{63}Ni to be periodically leak tested. The test is best performed by wiping the external surface of the detector around the outlet post with a moist swab which is then analysed for removable activity by liquid scintillation counting either in the laboratory or by a commercial service. Leak tests need not be performed on ^{63}Ni EC detectors when held in storage in the original shipping container prior to initial installation. Tritium (^{3}H) EC detectors release low levels of ^{3}H gas into the laboratory atmosphere and thereby contribute unnecessary radiation exposure to personnel. For this reason, the CNSC requires that these devices not be vented to occupied areas.

The current CNSC regulations require that all ^{63}Ni EC detectors be leak tested once every year. Therefore, it is mandatory that all ^{63}Ni EC detectors in use be leak tested by June 30 of every year. Information regarding leak testing by a commercial laboratory is available from your representative on the RSC; the cost is about $30 per detector. The leak-test reports will be maintained by the user group and made available for inspection by the CNSC and by your representative on the RSC (in August of every year). Copies also to be supplied to the RSO.

Note on new detector purchases: As noted in section 2.VI you must obtain the RSO's signature and CNSC licence number on your requisition before submitting it to your administrative officer for processing.

XIV. TRANSPORTATION

No special permission is required to transport radioactive materials aboard research vessels for research purposes provided all the rules and regulations are met (see 2.IV). Transport by any other means to or from locations outside the CCIW complex must be discussed with the RSO. (This excludes transport of radwaste to AECL as per 2.X) Any such transportation will be permitted only if it conforms to the requirements detailed in the "Packaging and Transport of Nuclear Substances Regulations" (Canadian Nuclear Safety Commission) read in conjunction with "Regulations Respecting the Handling, Offering for Transport and Transporting of Dangerous Goods".

XV. CONTACT WITH THE CNSC

The CNSC maintains contact with the CCIW through an authorized contact person only. The RSO acts as the contact person for the CNSC licence applicable to CCIW. Unauthorized contact with the CNSC should be avoided as it only creates confusion. Direct all your queries to the RSO.

APPENDICES

APPENDIX I

CANADA CENTRE FOR INLAND WATERS

DESIGNATED RADIOISOTOPE LABORATORY PERMIT

This Laboratory (   ) is authorized to store radioisotopes as follows:

Total α-emitters	10 µCi (370 kBq)
Total low-energy β-emitters (up to 0.3 MeV)	1 mCi (37 Mbq)
Total high-energy β-emitters (> 0.3 MeV)	100 µCi (3.7 Mbq)
Total γ-emitters	100 µCi (3.7 Mbq)

Exceptions	^{14}C	25 mCi (925 Mbq)
	^{3}H	25 mCi (925MBq)
	^{32}P	1 mCi (37 Mbq)
	^{33}P	1 mCi (37 Mbq)

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Radioactive Source

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____

____

Contact Person ____________________ Ext. ________

____________________ ____________________

CCIW Radiation Safety Officer   Expiry Date

APPENDIX II

CANADA CENTRE FOR INLAND WATERS

RADIOISOTOPE GROUP USER PERMIT

AUTHORIZED USERS: ______________________________ (Study Leader)

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____

____

LOCATION: ____

____

____

RADIOISOTOPES (QUANTITY): ____

____

____

DECLARATION: I declare that all the radioisotope work will be carried out in compliance with measures detailed in the CCIW Radiation Protection Manual. I also declare that all users are properly trained in radioisotope techniques and are aware of possible hazards.I assume the responsibility for cleaning up any accidental spills, etc.,occurring during the experimental work as determined by radiation surveys carried out by us before and after the experiment.

(Signature) ____

(Responsible Study Leader / Supervisor)

Approved ______________________________ Expiry Date ______________

CCIW Radiation Safety Officer

APPENDIX III

CANADA CENTRE FOR INLAND WATERS

NOTICE OF INTENT TO USE RADIOISOTOPES

ABOARD RESEARCH VESSELS

DATE: ____________________

R/V: ____________________

STUDY LEADER: ____________________

AFFILIATION: ____________________
(e.g., NWRI, GLLFAS, Other)

CRUISE NO.: ____________________

CRUISE PERIOD: ____________________
From To

CRUISE AREA: ____________________

RADIOISOTOPE(S) TO BE USED: ____________________

____

CHEMICAL FORM (e.g., $NaH^{14}CO_3$; soln.): ____________________

____

ACTIVITY: Total ____________ Bq. Date: ____________________

Per Sample ____________ Bq.

FORM OF WASTE: (e.g., solid, org. liquid, etc.) ____________________

____

____

MODE OF WASTE DISPOSAL: (Users are reminded that wastes are not to be disposed of in the study area)

____

____

____

NAME(S) OF EXPERIMENTERS:

1. ______________________________ (Study Leader)
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

CNSC LICENCE NO: (For experimenters not affiliated with the CCIW) ____________________

DECLARATION:

I declare that all the radioisotope work, as detailed above, will be carried out in accordance with the "Rules for Working with Radioisotopes in a Basic Laboratory" read in conjunction with the "CCIW Radiation Protection Manual". I also declare that all the experimenters involved are properly trained in radioisotope handling procedures and are aware of any possible hazards. I also assume the responsibility for cleaning up any accidental spills, etc., occurring during the course of this work as determined by radiation surveys carried out by us before and after the experiment.

Signature (Study Leader) ____________________________________

Approved: ____________________________ Date: ____________

(CCIW Radiation Safety Officer)

APPENDIX IV

CANADA CENTRE FOR INLAND WATERS

NOTICE OF INTENDED USE OF RADIOISOTOPES

BY NON-CCIW STAFF

NAME OF NON-CCIW STAFF: ____________________

AFFILIATION: ____________________

____

____

CNSC LICENCE NO: ____________________

ARE YOU TRANSPORTING ANY RADIOACTIVE MATERIAL TO CCIW? ____________

IF YES, ARE YOU ALLOWED TO DO SO BY THE CNSC? ____________

SUMMARY OF RADIOISOTOPE WORK TRAINING/EXPERIENCE:

____

____

____

____

____

____

RADIOISOTOPE(S) TO BE USED: ____________________

ACTIVITY: ____________________ DATE: ____________

DURATION OF EXPERIMENT: ____________________

LOCATION OF EXPERIMENT: ____________________

(Signature) ____________________

DECLARATION BY THE COLLABORATING CCIW STAFF:

I declare that all the radioisotope work detailed above will be carried out in compliance with the rules and regulations detailed in the CCIW Radiation Protection Manual. I assume the responsibilities of a Study Leader in this regard.

(Signature) ____________________

Approved: ____________________ Date: ____________

(CCIW Radiation Safety Officer)

COLLABORATORIVE RADIOISOTOPE WORK REQUIREMENTS

Canadian Nuclear Safety Commission recommended the following to be instituted in our Radiation Safety Protocols as regards non-CCIW staff collaboratoring with CCIW staff. This applies only to work with radioisotopes in locations of licensed activities as listed on our Radioisotope Licence, i.e., CCIW, Glenora and the Limnos.

The following must be provided in every instance of such collaboration;

- A notice of Intent To Use Radioisotopes Aboard Research Vessels (if the work is carried out aboard the Limnos) and the Notice of Intended Use Of Radioisotopes By Non-CCIW Staff (regardless of location).
- A copy of the non-CCIW staff person's CNSC Radioisotope Licence or, in the case of foreign non-CCIW staff, a copy of their Radioisotope Licence issued by their country's Nuclear Regulatory Agency.
- A copy of the non-CCIW staff person's identification and proof of receipt of Radiation Safety Awareness training.
- The non-CCIW staff person must be supervised by the authorized collaborating CCIW staff member or a member listed on his or her Radioisotope Group User Permit.
- The non-CCIW collaborator must provide a copy of the purchase order for their radioisotope, a use record for the isotope, a description and inventory for the isotope's disposal and a contamination monitoring report.

Copies to be provided to both the CCIW collaborator and the RSO. Copies of everything must accompany collaborators on board the Limnos. Copies of the first two permits above must be provided to the Ships OIC prior to departure and a copy of contamination monitoring reports on completion of the work.

John FitzGerald, RSO

APPENDIX V

CANADA CENTRE FOR INLAND WATERS

RADIOISOTOPE INVENTORY

GENERAL:

Purchaser/Study Leader ______________________ Location ____________________

Date Received ______________________

Radioisotope ______________________

Activity ______________________

Expected Duration of Use ______________________

RECORD OF WITHDRAWAL:

Date	Amount Withdrawn	Amount Left

WASTE DISPOSAL:

Date	Type of Waste	How Disposed	Amount

(Signature) ______________________________

Study Leader

APPENDIX VI

CANADA CENTRE FOR INLAND WATERS

RADIOACTIVE CONTAMINATION SURVEY RESULTS

Laboratory: ____________ Supervisor: ________________

Division/Organization: ___________________ Date: ____________

Method/Instrument: ________________________

Areas Surveyed	Results	Comments
	Benches	
	Floors	
	Fume Hoods	
	Cold Room	
	Centrifuge	
	Incubator	
	Other	

Swipe Test:

Remarks:

Surveyed by: ________________________

Note: 1 Bq = 1 disintegration per second

q.cm-2 = counts per second
(fractional efficiency of monitor x monitored area)

Loose contamination on working surfaces must not exceed: 3 Bq/cm^2 for Class A isotopes, 30 Bq/cm^2 for Class B isotopes, and 300 Bq/cm^2 for Class C isotopes. Contamination on all other areas must be less than 10% of above.

The radiation monitor must be properly calibrated and the efficiency calibration should be checked periodically.

APPENDIX VII

CANADA CENTRE FOR INLAND WATERS

DISPOSAL OF LIQUID SCINTILLATOR WASTE

I certify that the waste listed below, left with Material Management for disposal, contains less than 1 EQ, or less than the quantity/kg stated in Column 2 of Disposal Table 3, and as such, is considered non-radioactive:

Description of Waste

____

____

____

____

____

____

(Signature) ______________________________

(Study Leader)

Person Disposing of Waste ______________________

Telephone ______________________

APPENDIX VIII

CANADA CENTRE FOR INLAND WATERS

DESIGNATED RADIOACTIVE SEALED SOURCE PERMIT

This Laboratory (   ) is authorized to possess sealed source radioisotopes as follows:

Radioactive Source, Activity, Serial #, Instrument ID, Lab:

____
____
____
____
____
____
____
____
____
____

Authorized Users/Operators:

____
____
____
____
____

Responsible Person: ____________________ Branch: ________ Ext. ________

__________________________ ________________

CCIW Radiation Safety Officer Expiry Date

^3H	RADIONUCLIDE SAFETY DATA SHEET	H-3

PHYSICAL DATA

RADIATION: Beta (100% abundance)

ENERGY: Max. 18.6 keV, Average 5.7 keV

HALF LIFE:
- Physical $T_{1/2}$: 12.3 years
- Biological $T_{1/2}$: 10 -12 days
- Effective $T_{1/2}$: 10-12 days*

* Large liquid intake (3-4 litres/day) reduces Effective $T_{1/2}$ by a factor of 2+; ^3H is easily flushed from the body.

SPECIFIC ACTIVITY: 9650 Ci/g [357 TBq/g] max.

BETA RANGE:
- Air: 6 mm [0.6 cm, 0.25 inches]
- Water: 0.006 mm [0.0006 cm, 3/10,000 inches]
- Solids/Tissue: Insignificant, [No betas pass thru the dead layer of skin.]

RADIOLOGICAL DATA

Radiotoxicity: Least radiotoxic of all nuclides

Tritiated water: 1.73 E-11 Sv/Bq (0.064 mrem/uCi) of ^3H intake
Organic compounds: 4.2 E-11n Sv/Bq (0.16 mrem/uCi) of ^3H intake

Critical Organ: Body water or tissue
Exposure Routes: ingestion, inhalation, puncture, wound, skin contamination, absorption.
Radiological Hazard: External exposure - none from weak betas
Internal exposure and contamination - primary concern.

SHIELDING

None required - not an external radiation hazard.

DOSIMETRY MONITORING

Urine bioassay is the only readily available method to assess intakes. Bioassay may be required if monthly usage exceeds 100 mCi.

DETECTION AND MEASUREMENT

Portable survey meters will not detect lab quantities of ^3H. Liquid scintillation counting is the only readily available method for detecting ^3H.

C^{14}	RADIONUCLIDE SAFETY DATA SHEET	C-14

PHYSICAL DATA

RADIATION:	Beta (100% abundance)	
ENERGY:	Max. 156 keV, Average 49 keV	
HALF LIFE:	Physical $T_{½}$:	5730 years
	Biological $T_{½}$	12 days
	Effective $T_{½}$:	Bound 12 days; unbound - 40 days
SPECIFIC ACTIVITY:	4.46 Ci/g [0.165 TBq/g] max.	
BETA RANGE:	Air:	2 cm [10 inches]
	Water/tissue:	0.28 mm [0.012 inches]
	[1% of ^{14}C betas transmitted through dead skin layer, ie 0.007 cm depth]	
	Plastic:	0.25 mm [0.010 inches]

RADIOLOGICAL DATA

Radiotoxicity:	6.36 E-12 Sv/Bq (0.023 mrem/uCi) of $^{14}CO_2$ inhaled 5.64 E-10 Sv/Bq (2.09 mrem/uCi) organic compounds inhaled/ingested
Critical Organ:	Fat tissue [most labeled compounds]; bone [some labeled carbonates.]
Exposure Routes:	ingestion, inhalation, puncture, wound, skin contamination,absorption.
Radiological Hazard:	External exposure - none from weak betas when in lab containers. Prevent direct skin contact. Internal exposure and contamination - primary concern.

SHIELDING

None required - mCi quantities not an external radiation hazard.

DOSIMETRY MONITORING

Urine bioassay is the only readily available method to assess intakes. Bioassay may be required if monthly usage exceeds 5 mCi, or after any accident in which an intake is suspected.

DETECTION AND MEASUREMENT

Portable Survey Meters: Geiger Mueller type, pancake probes etc; - 10% efficient
Wipe Tests: Liquid Scintillation Counting ; is the best readily available method for counting ^{14}C.

^{32}P	RADIONUCLIDE SAFETY DATA SHEET	P-32

PHYSICAL DATA

RADIATION: Beta (100% abundance)

ENERGY: Max. 1,710 keV, Average 695 keV

HALF LIFE:
Physical $T_{½}$: 14.29 days
Biological $T_{½}$: Bone ~ 1155 days, Whole body 257 days
Effective $T_{½}$: 14.29 days*

SPECIFIC ACTIVITY: 286,500 Ci/g [10,600 TBq/g] max.

BETA RANGE:
Air: 610 cm [240 inches, 20 feet]
Water: 0.76 cm [0.33 inches]
Plastic: 0.61 cm [3/8 inches]

RADIOLOGICAL DATA

Radiotoxicity: Inhaled: 2.6E-8 Sv/Bq (95 mrem/uCi) Lung; 4.2E-9 Sv/Bq [16mrem/uCi]
Ingested: 8.1E-9 Sv/Bq [30 mrem/uCi] Marrow; 2.4E-9 Sv/Bq [8.8 mrem/uCi]

Critical Organ: Bone [soluble ^{32}P]; Lung [inhalation]; GI Tract [ingestion, soluble compounds]

Exposure Routes: ingestion, inhalation, puncture, wound, skin contamination, absorption.

Radiological Hazard: External exposure - unshielded dose rate from 1 mCi ^{32}P at vial mouth approximately 26 Rem/hr. Avoid direct contact with skin.
Internal exposure and contamination also significant concern.

SHIELDING

Minimum 0.6 cm plastic, Lucite, etc or until dose rate falls below 2 mR/hr.

DOSIMETRY MONITORING

Dosimeters, body or extremity, should be worn when handling lab quantities of ^{32}P.

DETECTION AND MEASUREMENT

Portable Survey Meters with beta capability : should be used to estimate beta dose rate during work with mCi quantities.
Portable Survey Meters: Geiger Mueller, pancake type detectors are good for monitoring contamination.
Wipe Tests; Liquid scintillation counting will detect contamination easily.

^{33}P	RADIONUCLIDE SAFETY DATA SHEET	P-33

PHYSICAL DATA

RADIATION:	Beta (100% abundance)	
ENERGY:	Max. 248.5 keV, Average 76.4 keV	
HALF LIFE:	Physical $T_{½}$:	25.3 days
	Biological $T_{½}$:	Bone - 1155 days, Whole body 257 days
	Effective $T_{½}$:	25.3 days*
SPECIFIC ACTIVITY:	156,000 Ci/g [5,780 TBq/g] max.	
BETA RANGE:	Air:	50 cm [20 inches]
	Water:	0.06 cm [0.024 inches]
	Plastic:	0.05 cm [0.02 inches]

RADIOLOGICAL DATA

Radiotoxicity:	15.6 mrem/uCi [Lung], 2.3 mrem/uCi of ^{33}P inhaled. 1.85 mrem/uCi [Bone marrow], 0.92 mrem/uCi of ^{33}P ingested.
Critical Organ:	Bone [soluble ^{33}P]; Lung [inhalation]; GI Tract [ingestion, soluble compounds]
Exposure Routes:	ingestion, inhalation, puncture, wound, skin contamination, absorption.
Radiological Hazard:	External exposure - mCi can be shielded by normal laboratory ware, either glass or plastic. Avoid direct contact with skin. Internal exposure and contamination - primary concern.

SHIELDING

Laboratory glassware and plastic ware provides sufficient shielding.

DOSIMETRY MONITORING

Urine bioassay may required when large quantities are used with significant frequency. Beta energy of ^{33}P is too low to be detected by most dosimeters.

DETECTION AND MEASUREMENT

Portable Survey Meters: Geiger Mueller, pancake type detectors are good for monitoring contamination.
Wipe Tests; Liquid scintillation counting will detect contamination easily.

^{35}S	RADIONUCLIDE SAFETY DATA SHEET	S-35

PHYSICAL DATA

RADIATION:	Beta (100% abundance)	
ENERGY:	Max. 167.4 keV, Average 48.8 keV	
HALF LIFE:	Physical $T_{½}$:	87.44 days
	Biological $T_{½}$:	623 days, [unbound ^{35}S] 90 days [bound ^{35}S]
	Effective $T_{½}$:	44-76 days [unbound ^{35}S]
SPECIFIC ACTIVITY:	42,707 Ci/g [1,580 TBq/g] max.	
BETA RANGE:	Air:	26 cm [10.2 inches]
	Water:	0.32 cm [0.015 inches]
	Plastic:	0.25 cm [0.010 inches]

RADIOLOGICAL DATA

Radiotoxicity:	2.48 mrem/uCi of ^{35}S inhaled. 0.733 mrem/uCi ^{35}S ingested.
Critical Organ:	Testis
Exposure Routes:	ingestion, inhalation, puncture, wound, skin contamination, absorption.
Radiological Hazard:	External exposure - weak beta is easily shielded by lab ware, either glass or plastic. Avoid direct contact with skin. Internal exposure and contamination - primary concern.

NOTE: ^{35}S Methionine - can volatilize into gas and present inhalation hazards during certain processes.

SHIELDING

Laboratory glassware and plastic ware provides sufficient shielding.

DOSIMETRY MONITORING

Urine bioassay may required when large quantities are used with significant frequency. Beta energy of ^{35}S is too low to be detected by dosimeters.

DETECTION AND MEASUREMENT

Portable Survey Meters: Geiger Mueller, pancake type detectors are good for monitoring contamination.
Wipe Tests; Liquid scintillation counting will detect contamination easily.

^{45}Ca	RADIONUCLIDE SAFETY DATA SHEET	Ca-45

PHYSICAL DATA

RADIATION:	Beta (100% abundance)	
ENERGY:	Max. 257 keV, Average 77 keV	
HALF LIFE:	Physical $T_{½}$:	162.6 days
	Biological $T_{½}$:	Bone ~ 18,000 days,
	Effective $T_{½}$:	163 days
SPECIFIC ACTIVITY:	17,800 Ci/g [659 TBq/g] max.	
BETA RANGE:	Air:	52 cm [20 inches]
	Water:	0.062 cm [0.024 inches]
	Plastic:	0.053 cm [0.021 inches]

RADIOLOGICAL DATA

Radiotoxicity:	35.8 mrem/uCi [Lung], and 16.2 mrem/uCi [Bone] of ^{45}Ca inhaled. 19.4 mrem/uCi [Bone], and 3.2 mrem/uCi [CEDE] of ^{45}Ca ingested.
Critical Organ:	Bone, lung, [inhalation]
Exposure Routes:	ingestion, inhalation, puncture, wound, skin contamination, absorption.
Radiological Hazard:	External exposure - weak beta is easily shielded by lab ware, either glass or plastic. Avoid direct contact with skin. Internal exposure and contamination - primary concern.

SHIELDING

Laboratory glassware and plastic ware provides sufficient shielding.

DOSIMETRY MONITORING

Urine bioassay may be required when large quantities are used with significant frequency. Beta energy of ^{45}Ca is too low to be detected by dosimeters.

DETECTION AND MEASUREMENT

Portable Survey Meters: Geiger Mueller, pancake type detectors are good for monitoring contamination.
Wipe Tests; Liquid scintillation counting will detect contamination easily.

^{55}Fe	RADIONUCLIDE SAFETY DATA SHEET	Fe-55

PHYSICAL DATA

RADIATION: Gamma/X-rays: 6 kev (25% abundance); 7 keV (~3%)
Auger electrons: 5.2 keV [average]

HALF LIFE:
Physical $T_{½}$: 2.70 years
Biological $T_{½}$: 11.9 years
Effective $T_{½}$: 2.2 years

SPECIFIC ACTIVITY: 2.40E3 Ci/g [89 TBq/g] max.

RADIOLOGICAL DATA

Radiotoxicity: 1.64E-10 Sv/Bq (0.61 mrem/uCi) of ^{55}Fe ingested [CEDE]
7.26E-10 Sv/Bq (2.69 mrem/uCi) of ^{55}Fe inhaled [CEDE]

Critical Organ: Spleen, [blood]
Exposure Routes: ingestion, inhalation, puncture, wound, skin contamination, absorption.
Radiological Hazard: Internal exposure - contamination - primary concern.

SHIELDING

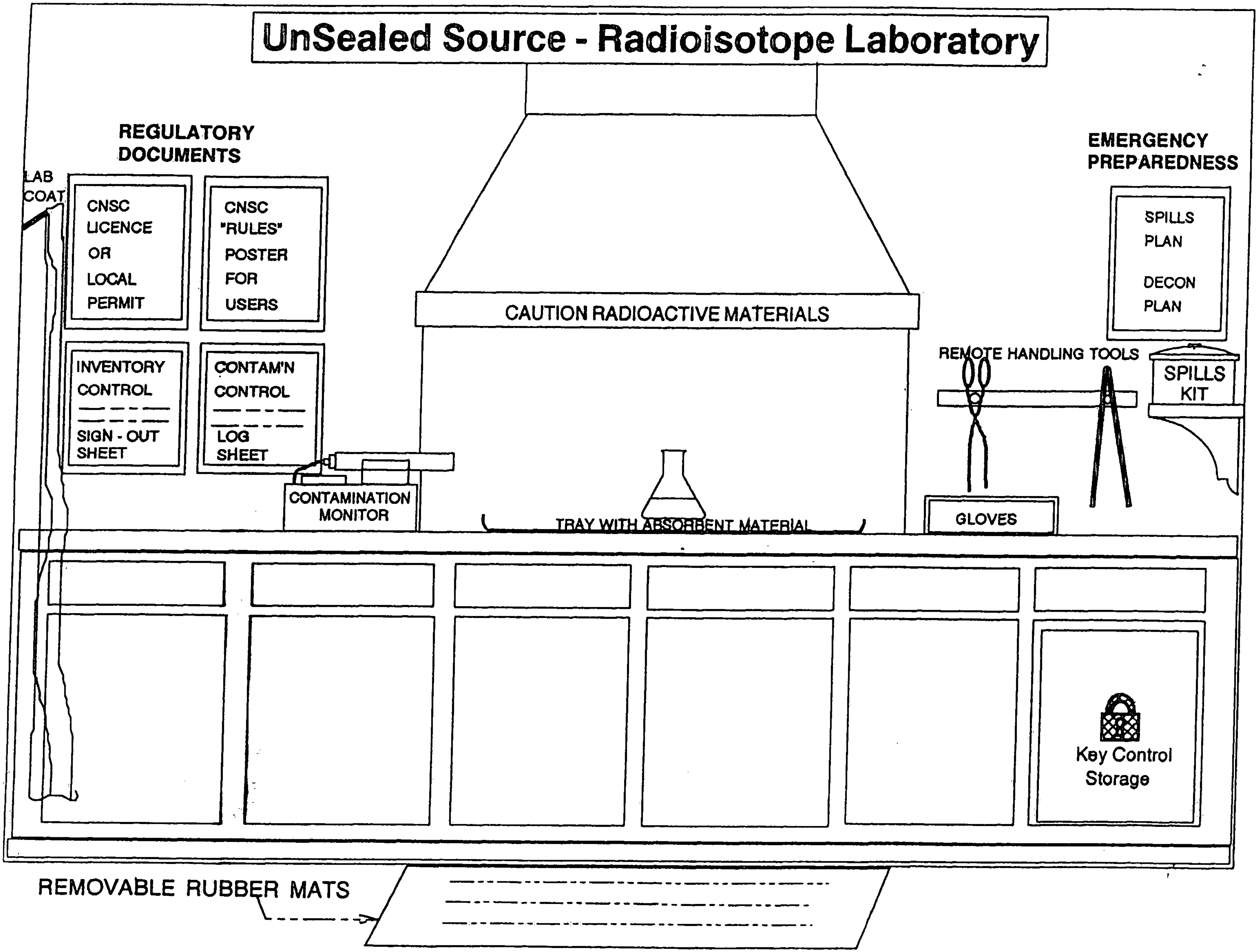
Little or none required. Not considered an external hazard in lab quantities.

DOSIMETRY MONITORING

Dosimeters not required at lab levels. If intake is suspected then blood sample may be taken.

DETECTION AND MEASUREMENT

Portable Contamination Meters: Geiger Mueller, pancake type detectors are good for monitoring contamination.
Wipe Tests; Liquid scintillation counting will detect contamination easily.



UnSealed Source - Radioisotope Laboratory
REGULATORY DOCUMENTS
LAB COAT
CNSC LICENCE OR LOCAL PERMIT
CNSC "RULES" POSTER FOR USERS
INVENTORY CONTROL
SIGN - OUT SHEET
CONTAM'N CONTROL
LOG SHEET
CONTAMINATION MONITOR
CAUTION RADIOACTIVE MATERIALS
TRAY WITH ABSORBENT MATERIAL
EMERGENCY PREPAREDNESS
SPILLS PLAN
DECON PLAN
REMOTE HANDLING TOOLS
SPILLS KIT
GLOVES
Key Control Storage
REMOVABLE RUBBER MATS

RADIOACTIVE SPILL
EMERGENCY PROCEDURES

MAJOR SPILL...involves a stock vial of radioactive solution or a large area.

☞ *CONTROL the spill*

- CONTAIN, COLLECT, or COVER the spill using absorbent materials. Often a paper towel with spill information written on it can be used to cover, absorb, and identify small spills.

☞ *IDENTIFY the spill with WARNING SIGNS*

- Post signs at all entrances to large spill areas.

☞ *ISOLATE AND SECURE the spill area*

- CONTROL OR DIVERT TRAFFIC if a large area is involved.
- close and secure doors

☞ *CHECK PERSONAL CONTAMINATION*

- use a monitor to check yourself thoroughly for surface contamination. You may have to leave the area to do this properly.

☞ *REPORT THE SPILL DETAILS TO SUPERVISORS OR RADIATION SAFETY OFFICER*

- you'll probably need help with a large spill
- wait nearby until help arrives.

If YOU have become contaminated begin decontamination immediately as follows.

☞ *PERSONAL DECONTAMINATION PROCEDURES* ☜

> Remove all contaminated clothing.
> Monitor for hot spots on skin and work on these first.

RADIOACTIVE LIQUIDS ...draw wet material from the skin more cleanly by using the wick action of absorbent materials.
Rinse affected skin thoroughly with warm running water.
> Soak in decontamination solutions of warm soapy water or other appropriate solutions depending on chemical compound spilled.
> Repeat cycles of soaking and rinsing.

RADIOACTIVE POWDERS...loose powder can be shaken from the skin into plastic bags to contain it.
Adhesive tapes can be used to help lift the remaining powder from the skin.
Some materials can be effectively scraped from the skin with a razor.

MINOR SPILLS.. such as a few spilled low level samples do not need to be reported unless personal contamination is suspected.

RADIATION SAFETY OFFICER EMERGENCY EXT. 4779