RADIATION SAFETY TRAINING MANUAL

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FOREWORD

All personnel who are working with sources of ionizing radiation are required to be instructed in the basic principles of radiation protection and the potential risks of ionizing radiation. Radiation Safety Office personnel provide this generalized instruction as required under Pennsylvania DEP regulations. Authorized Users are required to provide time off the job for this training and should emphasize to their personnel the importance of these radiation worker training sessions. The Authorized User is also responsible for providing the necessary specialized training for the particular type of work being performed.

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ALI* values in mCi

CADMIUM	^{109}Cd
CALCIUM	^{45}Ca
CARBON	^{14}C
CHLORINE	^{36}Cl
CHROMIUM	^{51}Cr
INDIUM	^{111}In
IODINE	^{125}I
IODINE	^{131}I
PHOSPHORUS	^{32}P
PHOSPHORUS	^{33}P
RUBIDIUM	^{86}Rb
SODIUM	^{22}Na
SULFUR	^{35}S
TRITIUM	^{3}H

I. INTRODUCTION

This radiation safety manual provides a basic summary of the information which one should be familiar with before handling radioactive materials here at the University and Health Center Hospitals.

Four principal issues to be covered are:

1. Legal structure covering the possession, use, disposal, and transportation of radioactive materials, along with specific State and Federal regulations;

2. Health risks or harmful biological effects associated with exposure to ionizing radiation;

3. Radiation protection concepts or measures which can be taken to limit or reduce one's exposure to radiation;

4. The programs, policies, and requirements established by the Radiation Safety Office that govern the use of radioactive materials here at the University and Health Center Hospitals.

This information is intended to supplement, not to replace, the University's Radiation Safety Committee policy manual, Regulations Regarding the Safe Use of Sources of Ionizing Radiation. It still remains the responsibility of the Authorized User to provide specific instruction on safe radiation practices for the particular type of radiation work being performed in the laboratory.

II. OVERVIEW OF REGULATIONS, PROTECTION STANDARDS, AND RADIATION SAFETY ORGANIZATION

The University of Pittsburgh operates under a license and regulations set forth by the Commonwealth of Pennsylvania Department of Environmental Protection (DEP)--Bureau of Radiation Protection, Title 25, for the procurement, possession, transportation, and use of all radioactive materials. These regulations constitute the minimum acceptable requirements and include certain notices and instructions to workers. The summary of Title 10 CFR 19 and the Pennsylvania DEP "Notice to Employees" on the following pages provide additional information.

The University was required to obtain a license and develop a radiation safety program to assure compliance with these regulations and to institute and maintain this program to keep radiation exposures to both you and the general public "as low as reasonably achievable" (ALARA).

The organizational chart "University of Pittsburgh Organizational Structure for the Control of Radioactive Material" details the administrative structure at the University under which the possession and use of radioactive sources falls. For details concerning the relationships noted in this chart, see the policy manual Regulations Regarding the Safe Use of Sources of Ionizing Radiation.

FIGURE 1: NOTICE TO EMPLOYEES (DEP)

2900-FM-BRP0003 Rev. 1/2017

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF RADIATION PROTECTION

NOTICE TO EMPLOYEES

STANDARDS FOR PROTECTION AGAINST RADIATION; NOTICES, INSTRUCTIONS AND REPORTS TO WORKERS; INSPECTIONS; EMPLOYEE PROTECTION

In Title 25 of its Rules and Regulations, the Pennsylvania Department of Environmental Protection has established standards for your protection against radiation hazards and has established certain provisions for the options of workers engaged in work under a Department license or registration.

YOUR EMPLOYER'S RESPONSIBILITY

Your employer is required to:

1. Apply these Department of Environmental Protection regulations and any conditions of your employer's radioactive materials license to all work involving radiation sources.
2. Post or otherwise make available to you a copy of the Department of Environmental Protection regulations, licenses, and operating procedures which apply to work in which you are engaged, and explain their provisions to you.
3. Post Notice of Violation involving radiological working conditions, proposed imposition of civil penalties and orders.

YOUR RESPONSIBILITY AS A WORKER

You should familiarize yourself with these provisions of the Department of Environmental Protection regulations and operating procedures which apply to the work in which you are engaged. You should observe their provisions for your own protection and protection of your co-workers. If you observe a violation or possible safety concern, you should report it immediately to your supervisor or contact DEP. You may be personally subject to enforcement action if through deliberate misconduct you cause or attempt to cause a violation of DEP requirements or deliberately provide inaccurate or incomplete safety information to DEP or your employer.

WHAT IS COVERED BY THESE REGULATIONS

1. Limits on exposure to radiation and radioactive materials in restricted and unrestricted areas.
2. Measures to be taken after accidental exposure.
3. Personal monitoring, surveys, and equipment.
4. Caution signs, labels, and safety interlock equipment.
5. Exposure records and reports.
6. Options for workers regarding Department inspections.
7. Related matters.

REPORTS ON YOUR RADIATION HISTORY

1. The Department of Environmental Protection regulations require that your employer give you a written report if you receive an exposure in excess of any applicable limit as set forth in the regulations or the license. The basic limits for exposure to employees are set forth in Chapter 219 of the regulations. This chapter specifies limits on exposure to radiation and exposure to concentrations of radioactive material in air.
2. If you work where personal monitoring is required pursuant to Chapter 219:
   (a) Your employer must advise you annually of your exposure to radiation, and
   (b) You may request a written report of your radiation exposure when you leave your job.

INSPECTIONS

All activities involving radiation are subject to inspection by representatives of the Pennsylvania Department of Environmental Protection. In addition, any worker or representative of workers who believes that there is a violation of the Department regulations of the terms of the employer's license or registration with regard to radiological working conditions in which the worker is engaged may request an inspection by sending a notice of the alleged violation to the Bureau of Radiation Protection. The request must set forth the specific grounds for the notice and must be signed by the worker as the representative of the workers or the worker's self. During inspections, Department inspectors may confer privately with workers, and any worker may bring to the attention of the inspectors any past or present condition which that worker believes contributed to or caused any violation as described above.

INQUIRIES

Inquiries dealing with matters outlined above or other reports and correspondence can be sent to the Bureau of Radiation Protection, Pennsylvania Department of Environmental Protection, P.O. Box 8469, Harrisburg PA 17105-8469.

Telephone (717) 787-2480
Facsimile (717) 783-8965
Off-hours emergency, call PEMA: (717) 651-2001

AVAILABILITY OF DOCUMENTS AND REPORTING OF VIOLATIONS

All documents listed in this notice are available at the University of Pittsburgh Radiation Safety Office, 3500 Fifth Avenue, Suite 400, Pittsburgh, PA 15213. Report any condition which may lead to a violation of any regulatory requirement or unnecessary exposure to radiation and/or radioactive material to the Radiation Safety Office at 412-624-2728 or the University of Pittsburgh AlertLine at 1-866-858-4456 (callers can remain anonymous).

FIGURE 2: SUMMARY 10 CFR 19

USNRC Rules and Regulations: SUMMARY OF 10 CFR 19
Part 19 Notices, Instructions, and Reports to Workers; Inspections

Adopted in its entirety by PA DEP

19.1 PURPOSE

Establish requirements for the University to provide certain information to individuals participating in DEP licensed activities.

19.2 SCOPE

Applicable to all persons who receive, possess, use or transfer radioactive materials which are licensed by the DEP.

19.11 POSTING OF NOTICES TO WORKERS

The licensee (University of Pittsburgh) is required to post DEP NOTICE TO EMPLOYEES and a notice which describes certain documents (regulations, licenses, operating procedures, and notices of violation) and states where they may be examined.

19.12 INSTRUCTIONS TO WORKERS

All individuals working in or frequenting any portion of a restricted area shall be:

1. Informed of location and use of radiation sources and radioactive materials;
2. Instructed in health protection problems associated with exposure to radioactive materials or radiation, in precautions or procedures to minimize exposure, and the purpose of protective devices;
3. Instructed in and to observe applicable DEP regulations;
4. Instructed of their responsibility to report violations of DEP regulations or unnecessary exposure to the University RSO;
5. Instructed in emergency response procedures;
6. Advised as to the availability of their exposure records.

19.13 NOTIFICATION AND REPORTS TO INDIVIDUALS

All radiation exposure data for an individual engaged in licensed activities shall be reported to the individual:

1. Annually;
2. Within 30 days at the request of an employee formerly engaged in licensed activity controlled by the licensee;
3. When excessive exposure is received by an individual as stipulated in 10 CFR 20.2202 & 10 CFR 20.2203;
4. At the request of a worker who is terminating employment, a written record or estimate of current year exposure.

19.14 PRESENCE OF REPRESENTATIVES OF LICENSEES AND WORKERS DURING INSPECTIONS

1. The University shall allow inspection by DEP at all reasonable times.
2. DEP inspectors may consult privately with individual workers.
3. If an individual is authorized by workers to represent them, he shall be given the opportunity to accompany the inspector during physical inspection (there are specific instructions as to who is eligible to be a representative).

19.15 CONSULTATION WITH WORKERS DURING INSPECTIONS

1. DEP inspectors may consult privately with workers.
2. Workers may communicate privately with DEP inspectors.

19.16 REQUESTS BY WORKERS FOR INSPECTIONS

1. Any worker who believes that a violation of any regulation pertinent to the licensed activities exists may request an inspection. The request must be in writing and should specify the basis for the belief. It should be signed and sent to the Regional Office Administrator or to the DEP inspector. If specified, the individual's name will be withheld during subsequent action by the DEP.
2. After it is determined that the request is legitimate, the DEP will conduct an inspection.

19.17 INSPECTION NOT WARRANTED: INFORMAL REVIEW

1. Provision exists to appeal a decision that a complaint under 19.16 does not warrant an inspection.
2. If a request under 19.16 is rejected because of a deficiency in the mechanics of submitting the request, the individual will be so advised in writing and may submit a new complaint.

19.20 EMPLOYEE PROTECTION

The University shall in no way discriminate against any worker who has exercised any option afforded by 10 CFR 19.

19.30 VIOLATIONS

Provisions in these regulations allow injunctions, court orders, fines and imprisonment for violation of applicable regulations.

19.31 APPLICATION FOR EXEMPTIONS

Provisions in these regulations allow for granting exemptions from the requirements of regulations of 10 CFR 19.

III. RADIATION AND RADIOACTIVE DECAY

Radioactive materials have certain characteristics, such as the types of radiations emitted and the rate of emission. Knowledge of these characteristics is helpful in establishing protective controls for the use of the material.

A. RADIOACTIVITY

A nuclide is an atom with a particular number of protons and neutrons in its nucleus. A radionuclide is a nuclide that has the property of spontaneously converting part of its mass into energy and emitting this energy in the form of energetic particles and electromagnetic radiation. The radionuclide emits radiation. This property is called radioactivity and the actual event is referred to as radioactive decay, disintegration, or transformation.

For example, Hydrogen-1 (^{1}H) is composed of one proton and one electron. This is normal, stable hydrogen. Hydrogen-2 (^{2}H), also called deuterium or "heavy" hydrogen consists of one proton, one electron and one neutron. Deuterium is also stable. Hydrogen-3 (^{3}H), tritium, is composed of one proton, one electron, and two neutrons. Tritium is not stable, it is a radionuclide and a radioisotope of hydrogen.

When ^{3}H spontaneously converts part of its mass into energy and emits this energy in the form of energetic nuclear particles it yields helium-3, which is stable, plus energetic particles. All radionuclides eventually decay to stable nuclides. Strontium-90 is a radionuclide that decays into yttrium-90, also a radionuclide. Yttrium-90 subsequently decays into the stable nuclide zirconium-90. This is a series radioactive decay with ^{90}Sr being the "parent" and ^{90}Y the "daughter."

HALF-LIFE

The process of radioactive decay is spontaneous and the time when any particular atom will decay is not known. However, when large numbers of radioactive atoms are present, the fraction of atoms that will decay in a given time span (the decay rate) can be specified. A quantity that uniquely identifies the rate of decay is the half-life of the radionuclide. This is the time required for one-half of the atoms present to decay. The half-life is a useful measure because no two radionuclides have exactly the same half-life. Also, the half-life is unaffected by the chemical or physical environment of the atom.

ACTIVITY

The quantity of radioactive material present at a given time is usually expressed in terms of the rate of decay at that time.

Two basic units used to describe the amount of activity in a sample are the Curie and Becquerel.

1 curie (Ci) = 3.7×10^{10} disintegrations/sec. (dps)

1 millicurie (mCi) = 2.22×10^{9} disintegrations/min. (dpm)

1 microcurie (μCi) = 2.22×10^{6} disintegrations/min. (dpm)

1 becquerel (Bq) = 1 disintegration/sec. (dps)

The quantity of activity left after any time interval is given by the following equation:

$A = A_o e^{-\lambda t}$ where

A_o = activity of sample at some original time
λ = decay constant for the particular radioactive element $.693/T_{½}$
e = base of natural logarithms 2.718
t = elapsed time
$T_{½}$ = half-life of a particular radioactive element

SPECIFIC ACTIVITY

The concentration of radioactivity, or in general, the number of curies (or mCi or μCi) per unit mass or volume is defined by the specific activity.

Ex. Ci/g, Ci/mg, mCi/ml, Bq/g, etc.

B. FORMS OF IONIZING RADIATION

The manner in which a radionuclide will emit radiation is well defined and quite characteristic. The term "manner" refers to the type, energy and intensity of the radiation.

alpha particles - massive charged particles, identical in mass and charge with ^{4}He nuclei, that are emitted from the nucleus with discrete energies (for example, ^{238}U emits alpha particles)

beta particles - light charged particles that come in positive (positron) and negative (negatron) forms, have the same mass as an electron, and are emitted from the nucleus with a continuous range of energies up to some maximum energy, (for example, ^{22}Na emits positrons, ^{32}P, ^{3}H, ^{14}C, ^{35}S, and ^{131}I all emit negatrons)

gamma rays - electromagnetic radiation emitted from the nucleus with discrete energies (for example, ^{131}I, ^{125}I, ^{57}Co, ^{51}Cr, ^{137}Cs)

x-rays - electromagnetic radiation emitted from the electron shells of an atom with discrete energies (for example, ^{131}I, ^{125}I)

Two other types of radiation are generated in the material surrounding the radioactive atoms rather than by the radioactive atoms themselves. These are external bremsstrahlung and annihilation radiation.

external bremsstrahlung - consists of photons created by the acceleration of charged particles in the electromagnetic field of the nucleus. The photons are emitted with a continuous range of energies up to the maximum energy of the charged particle. For example, when phosphorous-32 (^{32}P) beta particles interact with certain materials, lead for example, significant external bremsstrahlung radiation fields can be generated.

annihilation radiation - consists of two 0.511 MeV photons formed by the mutual annihilation of a positive beta particle (positron) and an electron. For example, when fluorine-18 (^{18}F) positive beta particles interact with matter, annihilation radiation is emitted.

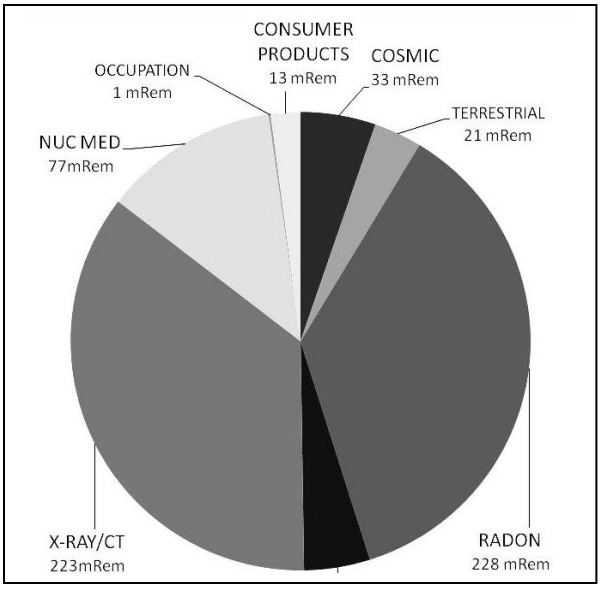
The energy of a radiation is typically given in units of electron volts (eV), kiloelectron volts (keV) or megaelectron volts (MeV). When the energy of a radiation is discrete or non-continuous, as in the case of gamma rays, it may be correctly said that a radionuclide "emits a 1 MeV gamma ray." A similar statement about radiation with a continuous range of energies, such as beta particles, is ambiguous because it could be referring to the mean or maximum energy of the radiation. Therefore, when specifying the energy of continuous radiation, it must be said that the radionuclide "emits a beta particle with a maximum energy of 1 MeV. The intensity of a radiation is the fraction of all decays that emit a particular radiation. For example, every time an ^{3}H atom decays, it emits a beta particle with a range of energies up to a maximum energy of 18 keV. The intensity of this beta is, therefore, 100%.

TABLE 1: SOURCES OF RADIOACTIVE MATERIAL AND BACKGROUND RADIATION
EFFECTIVE RADIATION DOSE IN THE UNITED STATES*

Natural Sources	
A. External to the body	
1. From cosmic radiations	33 millirem
2. From the earth	21
B. Inside the body	
1. Inhalation of air (Radon)	228
2. Elements found naturally in human tissues	29
Total, Natural sources	311
Man-made Sources	
A. Medical Procedures	
1. X-rays, CT, Fluoroscopy	223
2. Nuclear medicine, therapy	77
B. Occupational including atomic energy industry	<1
C. Consumer products (air travel, cigarettes, building material, mining and agriculture, combustion, highway construction, glass and ceramics)	13
Total, Man-made sources	313
Overall Total	**624** Millirems

* Estimated average dose, based on 2006 NCRP Report 160.

The contribution of various radiation sources to the total average effective dose equivalent in the U.S.



IV. BIOLOGICAL EFFECTS OF IONIZING RADIATION

A. UNITS OF EXPOSURE AND DOSE

Not all of the energy in a radiation field gets deposited in the living tissues of an individual who is in that field. Therefore, the distinction must be made between the amount of ionizing radiation that an individual is exposed to and the amount of energy that actually gets deposited in the body. Exposure is often expressed in units of **roentgens** which is a measure of the amount of ionization that the radiation (x- or gamma rays) could produce in air. The radiation energy that is absorbed in the body is referred to as the "dose" and is often measured in **rads or grays**. Doses from different types of radiation are not always additive. This is primarily because they deposit their energy differently as they pass through living tissue. A radiation that deposits its energy over a short range, like alpha, has the potential to cause more biological damage than a radiation that deposits its energy over a longer range, like x-rays. For radiation protection purposes, a factor is used to adjust for the quality of different radiations so doses can be added. The absorbed dose in rads is multiplied by this **quality factor** to yield dose equivalent units in **rems or sieverts**. Rems can be added to ensure that an individual has not received a dose in excess of the maximum permissible limits.

Roentgen (R)

A unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered X-rays in 1895.

Rad

Acronym for radiation absorbed dose. The basic unit of absorbed dose of radiation. A dose of one rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing material.

Gray

A joule per kilogram of absorbed energy.

Rem

Acronym for roentgen equivalent man. The unit of dose of any ionizing radiation that produces the same biological effect as a unit of absorbed dose of ordinary X-rays. Rem = Rad x Quality Factor (QF).

Sievert

A Gray x Quality Factor.

Quality Factor

The factor by which the absorbed dose is to be multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles and neutrons, can be more biologically damaging than other types, such as beta particles and x-rays.

Effective Dose Equivalent

The Dose Equivalent weighted for the relative probability of specific biological end points (fatal cancer and genetic damage). The weighting factor is designated W_T. Factors have been established for several types of tissue such as breast, gonadal, bone marrow, lung, thyroid, bone surfaces, and other organs. The units of Effective Dose Equivalent are either Rems or Sieverts.

B. ACUTE EFFECTS

The biological effects from exposure to ionizing radiation can be classified into two basic categories, acute and delayed. Acute effects are caused by relatively high doses of radiation delivered over a short period of time. These effects are dependent on how much and what area of the body is exposed over what time. The following two tables classify acute radiation injuries for different exposure levels to the skin (Table 2) and whole body (Table 3).

TABLE 2: ACUTE RADIATION INJURY TO THE SKIN

Dose in rads (Gy)	Effect
200-300 (2-3 Gy)	Epilation
>300 (>3 Gy)	Radiation dermatitis and erythema
1000-2000 (10-20 Gy)	Transepidermal injury
>2000 (>20 Gy) (single exposure)	Radio necrosis
>5000 (>50 Gy) (over extended period)	Chronic dermatitis

TABLE 3: SUMMARY OF EFFECTS ON HUMANS
OF SHORT-TERM WHOLE BODY EXTERNAL EXPOSURE TO RADIATION

Dose in rads (Gy)	Effects on humans
0 to 25 (0 - 0.25 Gy)	No detectable clinical effects. Delayed effects may occur.
25 to 100 (0.25 - 1 Gy)	Slight transient reductions in lymphocytes and neutrophils. Disabling sickness not common; exposed individuals should be able to proceed with usual tasks. Delayed effects possible, but serious effects on the average person very improbable.
100 to 200 (1 - 2 Gy)	Nausea and fatigue, with possible vomiting above 125 rads (1.25 gy) in about 20-25% of people. Reduction in lymphocytes and neutrophils, with delayed recovery. Delayed effects may shorten life expectancy (on the order of 1%).
200 to 300 (2 - 3 Gy)	Nausea and vomiting on first day. Latent period up to 2 weeks, perhaps longer. After latent period, symptoms appear but are not severe:loss of appetite, general malaise, sore throat, pallor, petechia, diarrhea, moderate emaciation. Recovery likely in about 3 months unless complicated by poor health or superimposed injury or infection.
300 to 600 (3 - 6 Gy)	Nausea, vomiting, and diarrhea in first few hours. Latent period with no definite symptoms perhaps as long as 1 week. Epilation, loss of appetite, general malaise, and fever during 2nd week, followed by hemorrhage, purpura, petechia, inflammation of mouth and throat, diarrhea, and emaciation in 3rd week. Some deaths in 2-6 weeks; possible eventual death to 50% of those exposed at about 450 rads (4.5 gy); convalescence of others about 6 months.
600 or more (>6 Gy)	Nausea, vomiting, and diarrhea in the first few hours. Short latent period, with no definite symptoms, in some cases during first week. Diarrhea, hemorrhage, purpura, inflammation of mouth and throat, and fever toward end of first week. Rapid emaciation and death as early as the second week, with possible eventual death of up to 100% of those exposed.

From: Saenger EL, ed, Medical Aspects of Radiation Accidents, p 9. US Atomic Energy Commission, Washington, DC, 1963.

C. DELAYED EFFECTS

Delayed effects of radiation are those which manifest themselves years after the original exposure. Delayed radiation effects may result from previous acute, high-dose exposure or from chronic low-level exposures over a period of years. It should be emphasized that there is no unique disease associated with the long-term effects of radiation; these effects manifest themselves in humans simply as a statistical increase in the incidence of certain already-existing conditions or diseases. The delayed effects observed from radiation exposure have been:

TABLE 4: DELAYED EFFECTS OF RADIATION

Genetic	Effects passed on from generation to generation due to mutation of genetic material
	or
Somatic	Effects manifested in exposed individuals include: Cancer Cataracts Developmental abnormalities in the fetus Growth retardation

Actual risk estimates for genetic and somatic effects from radiation exposure are described below in Tables 5 and 6. These risks can be compared to other health and occupational risks as tabulated in Tables 7 and 8.

TABLE 5: GENETIC RISKS OF LOW-LEVEL IONIZING RADIATION

One rem before conception is expected to produce 5-75 additional serious genetic disorders per 1 million live-births (First generation).

This is small in relationship to the usual incidence of genetic disorders of about 4.5% of live born off-spring ($45{,}000/10^6$ live-births)

TABLE 6: CANCER MORTALITY RISK ESTIMATES WHOLE-BODY LOW-LEVEL IONIZING FOR WHOLE-BODY LOW-LEVEL IONIZING RADIATION (BEIR V)

400	Excess Cancer deaths over a life-time are predicted per million persons exposed to 1 rad of radiation
4×10^{-4}	Excess Cancer deaths per person per rad over a lifetime
6×10^{-6}	Excess Cancer deaths per persons per rad per year

In a population of 10,000 persons four excess cancer deaths over a lifetime would be expected from an exposure of 1 rad to each person.

The expected deaths from cancer for 10,000 persons over a lifetime is normally 2500.

TABLE 7: ESTIMATED LOSS OF LIFE EXPECTANCY FROM HEALTH RISKS

HEALTH RISK	ESTIMATED AVERAGE DAYS OF LIFE EXPECTANCY LOST
Smoking 20 cigarettes/day	2370 (6.5 years)
Overweight (by 15%)	777 (2.1 years)
All Accidents combined	366
Auto accidents	207
Alcohol consumption (US avg)	365
Home accidents	74
Drowning	24
Natural background radiation, calculated	9.3
Medical radiation (63 mRem/yr avg), calculated	6.2
All catastrophes (earthquake, etc.)	4.8
1 rem occupational radiation dose, calculated	1.5
1 rem/yr from age 18-65, calculated	51

TABLE 8: ESTIMATED LOSS OF LIFE EXPECTANCY FROM INDUSTRIAL HAZARDS

INDUSTRY TYPE	ESTIMATES OF DAYS OF LIFE EXPECTANCY LOST
All industry	60
Trade	27
Manufacturing	40
Service	27
Government	60
Transportation and Utilities	160
Agriculture	320
Construction	227
Mining and Quarrying	167
Nuclear industry (Avg radiation dose of 0.45 rem/yr) from age 18-65, calculated	23

Information in Tables 7 and 8 from "Catalog of Risks Extended and Updated", Bernard L. Cohen, Health Physics Vol 61 No 3, September 1991.

V. BASIC RADIATION PROTECTION PRINCIPLES

A. RADIATION PROTECTION STANDARDS

TABLE 9: MAXIMUM PERMISSIBLE RADIATION DOSE LIMITS *

ADULT OCCUPATIONAL EXPOSURE		
Whole body	5 rem/yr TEDE	0.05 Sv/yr
Skin of whole body or extremity	50 rem/yr SDE	0.5 Sv/yr
Eye	15 rem/yr LDE	0.15 Sv/yr
Embryo/fetus	0.5 rem/gestation period TEDE	0.005 Sv
MINORS OCCUPATIONAL EXPOSURE	10% of Adult limits	
MEMBER OF GENERAL PUBLIC	0.1 rem/yr TEDE	0.001 Sv/yr

* Reference 10 CFR 20.1201, 1207, 1208, 1301

TEDE = Total Effective Dose Equivalent
SDE = Shallow Dose Equivalent
LDE = Lens of Eye Dose Equivalent

ALARA PHILOSOPHY

Current scientific evidence concedes that there may not be a risk-free level of radiation exposure. Therefore, in addition to providing an upper limit on a person's permissible radiation exposure, the DEP also requires that its licensees maintain occupational exposures as low as reasonably achievable (ALARA). This means that every activity involving exposure to radiation should be planned so as to minimize unnecessary exposure to individual workers and the worker population. All experimental procedures should be reviewed with the objective of reducing unnecessary exposures.

An ALARA program has been incorporated as part of the University's DEP license. It outlines the responsibilities of several groups. Management has the responsibility to provide an administrative organization and the resources to operate it. The University Radiation Safety Committee must review occupational radiation exposures. The Radiation Safety Officer ensures that training is given, will review authorized users' procedures and physical layouts, and will investigate radiation exposures that exceed ten percent of the annual limit. The Authorized User will ensure that laboratory personnel are properly trained and will consult with the RSO with regard to keeping exposures ALARA. The radiation worker will consider ALARA when conducting research in the laboratory and will consult with the Authorized User or the Radiation Safety Office when safety or other laboratory practices are in question.

The University of Pittsburgh has set an ALARA action level at 10 percent of the annual radiation exposure limits. Annual cumulative radiation exposures are reviewed each calendar quarter. Action levels are at 10%, 30% and 80% of the annual allowable dose. If it is determined through monitoring or calculation that any worker has exceeded 30 percent of the applicable radiation exposure limits, an investigation will be conducted to determine the cause of the exposure and to develop methods to control future exposures. A summary of exposure for any individuals exceeding these levels is presented to the University Radiation Safety Committee at its next quarterly meeting.

B. EXTERNAL RADIATION PROTECTION PRINCIPLES

TIME

Radiation doses are directly proportional to the exposure time in the field. If the time spent in a given radiation field is doubled, the worker's dose is doubled. Therefore, to limit radiation doses, the time spent in the field must be limited.

$$\text{Radiation Dose} \propto (\text{Time in field})$$

DISTANCE

The radiation dose received from a source is inversely proportional to the square of the distance of separation. If the distance is increased ten-fold the exposure will be cut down to one percent. Thus, the distance of separation between a person and a "point" source has a relatively greater influence on dose than the time factor.

$$\text{Radiation dose} \propto \frac{1}{(\text{Distance of Separation})^2}$$

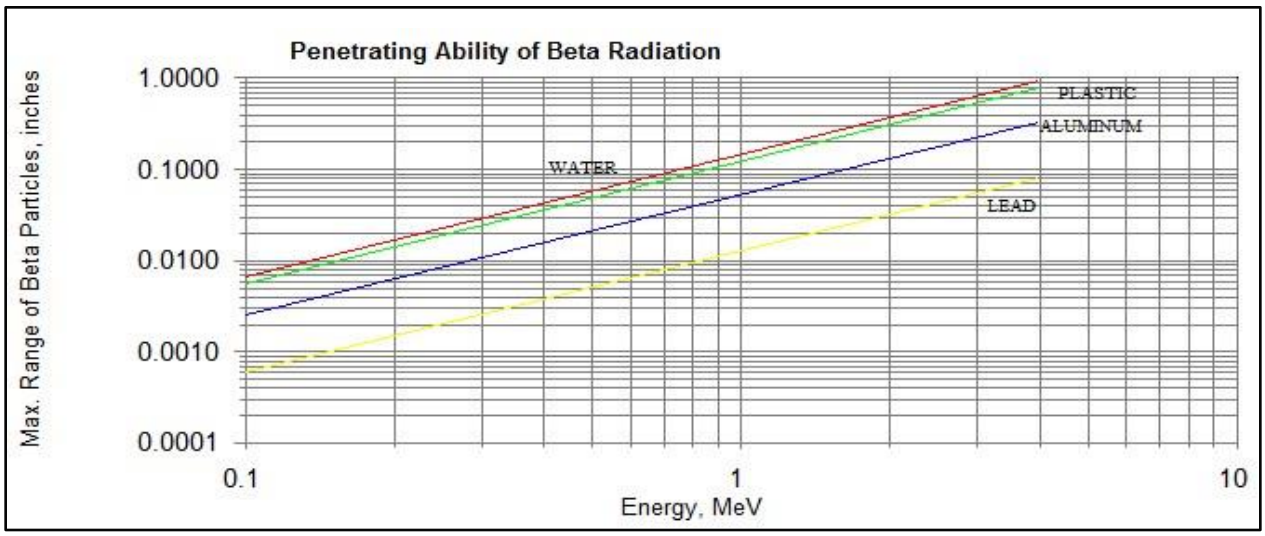
SHIELDING

Any substance may serve to attenuate radiation to acceptable levels provided sufficient thickness is used. Certain materials, however, are more effective in shielding certain types of radiation.

Alpha particles are stopped by an ordinary sheet of paper or a few inches of air.

Beta particles although more penetrating than alpha, can be absorbed readily and completely. Figure 4 shows the shielding required for complete absorption of beta rays of various energies in various substances. For example, beta rays of one million electron volts (MeV) are completely absorbed by 0.15 cm of aluminum.

FIGURE 3: MAXIMUM RANGE OF BETA PARTICLES AS A FUNCTION OF ENERGY



Radiation Health Handbook (Range in air≈Range in plastic x 1000)

Gamma rays and x-rays of a single energy (monoenergetic) are attenuated exponentially; therefore, theoretically it is not possible to attenuate the radiation completely, although the exposure rate can be reduced by any desired factor. Thus, if a certain thickness of absorber, the half-value layer (HVL), reduces the dose to one-half the initial amount, then a thickness of three such layers will reduce the dose to one-eighth (½ x ½ x ½) the initial amount. Similarly three tenth-value layers (TVL) will reduce the dose to 1/1000 of the initial amount (1/10 x 1/10 x 1/10). Shielding materials of high density and high atomic number, such as lead, are generally the most effective absorbers or shields for x- and gamma rays; therefore, less thickness and weight per square foot is required for such materials. Steel, concrete, brick, or other materials can provide the same degree of protection if used in appropriately greater thicknesses.

C. INTERNAL RADIATION PROTECTION PRINCIPLES

An internal radiation hazard exists when radionuclides can enter the body by ingestion or inhalation, through wounds, or by direct absorption through intact skin. The radiation doses are often difficult to evaluate and depend on many factors such as the physical and chemical form of the material, the mode of entry, and the individual's metabolism. A certain quantity of radioactive material within the body represents a greater hazard than the same activity as an external source because the tissue is irradiated continuously until the material has decayed or been eliminated. Even weakly penetrating radiations such as low-energy beta particles present a hazard since all their energy will be dissipated in the tissue.

The principal means of protection from internal radiation is containment of the radioactive source. Control measures must be taken to prevent the contamination of working surfaces, equipment, and personnel. The following covers some of these safety precautions and procedures.

D. GENERAL PRECAUTIONS AND SAFETY PROCEDURES WHEN WORKING WITH RADIOACTIVE MATERIALS

1. Be familiar with the particular clinical or experimental procedure being performed. Never perform extensive radiochemical work with hazardous levels of material until the procedure has been tested by a "dry run" to preclude unexpected complications.

2. Keep radioactive and non-radioactive work separate as much as possible by maintaining designated and labeled areas on the bench top and in the laboratory.

3. Cover work surfaces with absorbent padding that has a plastic backing to protect furniture and facilitate clean up. Use stainless steel or plastic trays to help control liquids if these are spilled.

4. Wear a laboratory coat and appropriate gloves for protection of clothes and skin. To avoid the spread of contamination, remove gloves at the work area. Change gloves frequently to prevent the spread of contamination. Do not handle faucets, light switches, door knobs, telephones, etc., with contaminated gloves. Special protection may be required for open cuts or wounds.

5. Monitor yourself for contamination at frequent intervals when working with radioactive materials. Monitoring should include hands, body, shoes, and protective clothing.

6. Clean up after yourself. Do not leave the laboratory contaminated or in a mess. Check all work areas for contamination. Before leaving the laboratory, wash your hands thoroughly.

7. Never pipette radioactive solutions by mouth. Mechanical devices must be used. Disposable tips are strongly recommended.

8. To prevent accidental ingestion of radioactive materials, do not eat, drink, smoke, store or prepare food, or apply cosmetics in restricted areas.

9. Do not handle sources of high radioactivity directly with your fingers. Use tongs.

10. Observe time, distance, shielding, and contamination control while working with radioactive materials or while in a radiation area.

11. If you have been issued a dosimeter, you should wear it at all times when working with or near radioactive materials.

12. Have containers for radioactive waste and contaminated lab ware at the work location. Avoid transporting contaminated articles from the work area through clean laboratory areas. Shield the waste containers as required to prevent unnecessary exposure.

13. Confine work with gaseous/volatile radioactive materials, or processes which can create dust or aerosols to fume hoods or glove boxes, whichever is appropriate.

14. Label containers of radioactive material clearly, indicating radionuclide, activity, compound, date, and radiation level, if applicable.

E. EMERGENCY PROCEDURES

In case of a spill of radioactive material, the following procedures should be performed:

1. Alert others in the laboratory that a spill has occurred.

2. Secure the area against traffic.

3. Contain and minimize the spread of contamination by covering the spill with absorbent material such as paper towels, padding, Kimwipes, etc,

4. Contact the Radiation Safety Office as soon as possible.

5. Taking the necessary precautions to limit exposure, determine the extent of contamination by monitoring the area with the appropriate survey instrument and/or by performing a smear survey.

6. To clean up the spill: Decontaminate the area in convenient sectors by starting from the outer edge with a wiping and scrubbing motion and working in towards the center. Use a commercial decontamination product or a soap and water cleaning solution on paper towels or pads. Other additives such as alcohol or EDTA may also be used, depending on the chemical form of the contamination. Sodium bicarbonate should be used with radioiodine spills to buffer the pH and reduce the volatilization of iodine gas.

7. Package the contaminated waste from the clean-up in a yellow bag and re-survey the area to make sure that there is no residual contamination.

8. The Radiation Safety Office will assist in the monitoring, clean up, and survey operations.

In case of personnel contamination, the following procedures should be performed:

1. Immediately remove any contaminated clothing or shoes, exercising caution not to spread or track the contamination further.

2. Wash contaminated areas of skin with soap and water. Do not use hot water and do not use abrasive scrubbing, as this will only increase the passage of radioactive material through the skin.

3. Call the Radiation Safety Office to evaluate the exposure.

In case of personnel injury:

1. Render appropriate first aid.

2. Decontaminate or wrap the contaminated area.

3. Seek medical attention.

4. Contact the Radiation Safety Office.

VI. RADIATION MONITORING AND DETECTION PRINCIPLES

A. DETECTION OF FIXED AND REMOVABLE CONTAMINATION

In facilities where radioactive materials are handled, personnel should regularly monitor themselves and their work area for fixed and removable contamination in order to:

1. Ensure that contamination control is maintained;
2. Ensure that contamination is not transferred to non-radioactive areas;
3. Provide feedback as to the effectiveness of contamination control measures;
4. Prevent unnecessary personnel exposure resulting from intake of contamination.

Contamination can be removable, fixed, or a combination of the two. Removable contamination represents a greater hazard. Methods of detection should be used which can detect fixed or removable contamination, and differentiate between the two.

The appropriate frequency and thoroughness of monitoring will depend on a variety of factors, including levels of activity handled, degree of containment, and control exercised. Individuals should monitor themselves and their clothing during and after each use. Laboratories where radioactive materials are used should be surveyed per the program requirements in VII G. Facilities that are shared with other users should be surveyed before and after each use.

Areas and items that should be monitored include hands, wrists, protective clothing, personal belongings, work surfaces, radioactivity processing and storage areas, and equipment and materials removed from radioactivity handling areas.

B. SELECTION OF APPROPRIATE INSTRUMENTS

Identify those radionuclides which are handled, and select the appropriate instrument(s) based on the need for portability, and the sensitivity of the instrument for the characteristic radiations emitted by the radionuclides in question. Use the following table as a guide.

TABLE 10: INSTRUMENT SELECTION GUIDE

CHARACTERISTIC RADIATION	PORTABLE INSTRUMENTS	NON-PORTABLE INSTRUMENTS
Low energy beta ^{3}H, ^{63}Ni	None	Liquid Scintillation Counter
Medium energy beta ^{14}C, ^{35}S	GM Probe (thin window only)	Liquid Scintillation Counter
High energy beta ^{32}P	GM Probe Gamma (NaI) Probe	Liquid Scintillation Counter
Low energy gamma ^{125}I	GM Probe Gamma (NaI) Probe	Gamma Counter or Liquid Scintillation counter
Medium-high energy gamma ^{131}I, ^{51}Cr	GM Probe Gamma (NaI) Probe	Gamma Counter or Liquid Scintillation counter

Additional instrument selection parameters include background radiation levels, ruggedness needed, and minimum delectability.

Portable instruments are often dedicated to a monitoring station where wipes and other items are brought for

contamination monitoring.

Note: The Radiation Safety Office has available a list of recommended survey instruments for use in research laboratories.

C. INSTRUMENT OPERATION

Familiarize yourself with instrument operating instructions. Check for proper instrument function, including recent calibration, battery strength or operating voltage, and response to check sources.

D. MONITORING FOR CONTAMINATION

To directly monitor a surface for contamination, bring the probe to within about one-half inch of the surface, being careful not to damage or contaminate the probe. If available, use the audio output to quickly locate contamination. Move the probe slowly over the surface (3-4 in/sec). Adjust meter range selector and observe the reading from a point directly above the meter face to ensure proper alignment of needle and scale. Since the readout will fluctuate, look for the average value. High background levels may be overcome by partially shielding the probe.

To test for removable contamination on surfaces and equipment, a smear or wipe is the appropriate methodology to use. Wearing gloves, firmly smear the surface in question with a filter, a paper smear or a piece of clean paper towel. A 1 inch diameter size is commonly used. Avoid cross contaminating the wipes while handling. Wiping a standard surface area, such as 100 cm^2, yields results which can be compared from survey to survey.

For beta emitters, totally immerse the wipe in an appropriate scintillation cocktail, agitate, and count by liquid scintillation counting. For gamma emitters, the dry wipe may be counted in a gamma counter. Alternately, bring the wipe to the window of a GM or NaI probe and rate-meter and note any increase in the count rate. Do not move the probe if doing so causes a change in the background count rate

A wipe survey is a qualitative, not a quantitative indication of surface contamination. Maintaining a uniformity in the procedure will permit comparisons between wipes and between surveys.

The amount of radioactivity that has been detected by direct monitoring or by wipe survey can be readily estimated by subtracting the background count rate (bkg counts/min) from the observed count rate (gross counts/min) and then dividing the net count rate by the counting efficiency (counts/disintegration) for the radionuclide in question.

$$\text{net disintegrations/min (dpm)} = \frac{\text{(gross cpm)-(bkg cpm)}}{\text{efficiency}}$$

Always express contamination levels in standard units, such as dpm or microcuries/100 cm^2. If the identity of the radionuclide detected is not known, the most conservative (lowest) efficiency of the possible radionuclides should be used.

VII. RADIATION SAFETY OFFICE POLICIES AND PROGRAMS

A. LABORATORY RULES AND PROCEDURES

The purpose of these rules and procedures is to provide a safe working environment for laboratory personnel, to ensure public safety, and to avoid contamination of equipment and facilities.

1. RADIATION LABORATORIES

   Radioactive materials may only be used and stored in specifically designated and approved areas. These "Radiation laboratories" are considered to be restricted areas, where access is controlled in order to protect individuals from exposure to radiation and radioactive materials. They will have a "Caution Radioactive Materials" label on the door or entrance area.

2. EQUIPMENT REPAIR, DISPOSAL

   All laboratory equipment where radioactive material is stored or processed (refrigerators, freezers, water baths, centrifuges, etc.) must be labeled with a “Caution Radioactive Material” label. Prior to repair, modification, placement into storage or disposal, the equipment must be monitored for contamination by RSO personnel.

3. HOUSEKEEPING

   Custodial personnel should only clean areas designated by the Authorized User. The users or their qualified laboratory personnel shall be responsible for the rest of the housecleaning. The Authorized User is responsible for ensuring that housekeeping personnel do not come in contact with radioactive contamination.

4. TERMINATION OF USE

   When the use or storage of a radioactive material in a facility is terminated, the RSO must be notified. Radiation Safety personnel will carry out a final survey of the laboratory before releasing the area for unrestricted use.

5. FOOD

   Eating, drinking, smoking, storage/preparation of food, and application of cosmetics are not permitted in radiation laboratories. This policy is not unique to the University of Pittsburgh. It is designed to minimize the risks of ingesting potentially harmful agents into the body.

   We interpret the presence of coffee mugs, drink containers, food in refrigerators or cold rooms, coffee makers, and microwave ovens as evidence that eating and drinking may be occurring in an area. Therefore, the Radiation Safety Office staff has been instructed to confiscate and dispose of any such materials found in a designated radiation laboratory, regardless of value.

B. SECURITY OF RADIOACTIVE MATERIALS

Background: Regulations pertaining to the security of radioactive materials require that "The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas," and that "the licensee shall control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage."

Policy: Radioactive materials are to be stored in a manner that will minimize the risk of breakage, leakage or theft. The use and storage of radioactive materials must either be under the constant surveillance and immediate control of a radiation worker or secured from unauthorized removal and access. These requirements are applicable to stock vials and non-exempt sealed sources.

Procedure: In accordance with the above policy the following shall be implemented:

RADIOACTIVE MATERIALS MUST BE USED AND/OR STORED IN POSTED ROOMS LISTED ON THE AUTHORIZED USER'S APPLICATION.

RADIOISOTOPE LABORATORIES ARE TO BE LOCKED WHEN UNOCCUPIED IF THERE ARE UNSECURED SOURCES OF RADIOACTIVE MATERIAL.

In unlocked and unoccupied laboratories, stock vials and non-exempt sealed sources must be secured in a locked container such as a cabinet, refrigerator, shield, hood or storage box.

ANY INDIVIDUAL WHO IS UNKNOWN TO LABORATORY PERSONNEL OR WHO IS UNFAMILIAR WITH THE WORK PRACTICES IN YOUR LABORATORY SHOULD BE "CHALLENGED" UPON ENTRY INTO AREAS IN WHICH MATERIALS ARE UNSECURED.

Exemptions: Small quantities of materials (liquid scintillation vials, gamma counting samples, etc.) in the process of being assayed in nuclear counting equipment. These materials are not exempt from proper handling and waste disposal procedures.

C. ORDERING AND RECEIPT OF RADIOACTIVE MATERIAL

All orders or requests for radioactive material must be approved by the Radiation Safety Office. Specific guidelines for procurement of radioactive materials may be found on the RSO website.

The Radiation Safety Office must be notified in writing prior to receipt of items which do not require a purchase requisition such as evaluation products, free samples, replacement orders, or radioactive materials from other research institutions.

With the exception of certain radioactive material for clinical or human use, all packages containing radioactive material must be received through the Radiation Safety Office, Hieber Building, Suite 400, and surveyed for contamination before being delivered to the User's laboratory. If significant contamination is found, or if there is a discrepancy between the material in the package and what is stated on the purchase request, the User will be notified. Special handling instructions or requirements associated with the use of the radioactive material will be noted on the package.

D. PACKAGE OPENING PROCEDURE

Packages of radioactive materials will be monitored in accordance with requirements specified in 10 CFR 20 and 25 PA Code 219. Special handling instructions or precautions will be provided, when needed, for packages of radioactive material which are received at the Radiation Safety Office, before they are delivered to the User's laboratory.

All packages of radioactive material, exclusive of where or by whom they are received, will be subject to the following safe opening procedure:

PROCEDURE FOR SAFELY OPENING PACKAGES CONTAINING RADIOACTIVE MATERIAL:

1. Disposable gloves should be worn in order to prevent potential hand contamination.

2. Visually inspect the package for any sign of damage; e.g., wet or crushed. If damage is noted, notify the Radiation Safety Office.

3. For volatile material, place the package in a vented fume hood.

4. Open the inner packaging and verify that the contents agree with the packing slip.

5. Check the integrity of the final source container. Look for broken seals or vials, loss of liquid, or discoloration of the packing material. If there is reason to suspect contamination, perform a wipe survey to determine if there is removable radioactivity. Take precautions against the potential spread of contamination.

6. If anything in steps 4 and 5 is other than expected, stop further handling and notify the Radiation Safety Office.

7. Remove or obliterate any radiation labels from packaging materials before discarding in the regular trash. If contaminated, treat this material as radioactive waste.

E. TRANSFER OF RADIOACTIVE MATERIALS TO OTHERS

Ordering and receipt of radioactive materials is limited to those researchers who have received authorization from the University Radiation Safety Committee. Radioactive material is received under the University of Pittsburgh's DEP licenses and may only be used in authorized University related facilities.

Transfers within University related facilities:

Transfer of radioactive material to other researchers is allowed, <u>but only when the following two steps are taken:</u>

1) Verify that the receiver is authorized to possess the isotope and
2) File a notification of the transfer with the Radiation Safety Office.

RSO form "Internal Radioisotope Transfer Record " should be completed and submitted to Hieber Building, Suite 400. This form is available on the Radiation Safety Office web site.

Transfers outside the University:

Radioactive material may only be transferred to individuals at other institutions by the Radiation Safety Office. ***Contact the Radiation Safety Office for assistance.*** Regulations require that the University have a written confirmation that the receiving institution is licensed for the material. Most institutions require, as we do, that all incoming material is delivered first to the Radiation Safety Office. U.S. Department of Transportation packaging requirements must be adhered to as well as the limitations imposed by the carriers such as UPS or FedEx. Improper shipments are subject to fines and legal action.

F. TRANSPORTATION OF RADIOACTIVE MATERIALS WITHIN THE UNIVERSITY COMPLEX UTILIZING PUBLIC PLACES

Radioactive materials (waste, stock vials or experiments in progress) are occasionally moved between laboratories on different floors or between buildings. Public hallways, elevators, stairwells and sidewalks are utilized. Every effort must be taken to minimize public exposures and prevent contamination.

Material must be in the possession of a trained radiation worker at all times. It may be hand carried or moved on a cart, but not transported in a vehicle. It is not acceptable to convey a radioactive package on a public transportation vehicle such as a campus van or public bus. If transport by vehicle is necessary, please consult with the Radiation Safety Office.

The material must be contained in a closed package or over pack, no open containers are permitted. As appropriate, consideration should be made for absorbent material and shielding.

Care should be taken when packaging the radioactive material so that the outside of the container and subsequently the carrier does not become contaminated.

Waste bags should be appropriately closed, with a proper label attached.

G. LABORATORY SURVEYS

Laboratory personnel are required to perform and document laboratory surveys in accordance with the following program:

Documented Radiation Laboratory Survey Program

Purpose

The purpose of a survey is to identify sources of radiation contamination and exposure. All laboratory personnel should be aware of these sources of exposure. Corrective action should be taken as necessary to insure a safe work environment. Documentation of radiation surveys must be retained. This policy does not eliminate the need for daily checks of the work place and routine surveys of personnel.

Frequency of Surveys

Surveys must be performed weekly in all laboratories where radioactive material was in use during that week.

"Use" means removal from stock vial for experiment and/or processing radio-labeled compounds or probes in open containers, waste handling or discharge to sink. Receipt and placement into storage of stock vials does not constitute use. Analysis of samples in liquid scintillation or gamma counters is not considered use of radioactive materials.

"Laboratories" do not include darkrooms, freezer/refrigerator rooms and counting equipment rooms. Common equipment rooms, and cold/warm rooms are considered to be laboratories; however, they are exempt from surveys by laboratory personnel **if** there is no use of unsealed radioactive material. Detection of contamination by the Radiation Safety Office will revoke the exempt status in these rooms.

Survey procedure

Meter surveys are required for all laboratories except those exclusively using H-3 or I-125 in RIA kits. Exemptions may be granted by the RSO for specific cases.

Perform a radiation survey with an operational portable survey instrument. Survey with detector end caps and beta shields removed. Select the most sensitive (lowest) range of the instrument. Turn the speaker on. Survey all work and storage areas, waste containers, accessible surfaces and Rad labeled equipment. Record (in CPM) the background reading and all readings above background on the report form.

Smear Surveys are required for all laboratories except those exclusively using microspheres.

Perform a contamination survey, taking smears representative of both Rad work and clean areas. A one inch dry paper filter or a cotton swab is an acceptable smear. For uniformity of results, smear an area of 100 cm^2 (four inch square). All areas with radiation levels above background should be smeared. Pay particular attention to areas which may have been contaminated, such as switches, handles, etc. Be careful to not inadvertently contaminate the smears or transfer contamination to a clean surface in the process.

Count smears with an appropriate instrument. Low energy beta emitters (C-14, H-3, S-35, Ca-45) must be counted in a liquid scintillation counter. Medium and high energy beta emitters or beta/gamma emitters may be counted with a thin window "GM" survey instrument. Smear analysis should be made in a low background environment. Photon emitters such as I-125 and Cr-51 should be counted in a gamma counter or with a thin crystal NaI detector.

Using the counting efficiency for the instrument selected (see table below), calculate dpm/smear. Record background and net (gross minus background) dpm on the survey report. Also record the counting instrument used.

Average Counting Efficiency for Standard Instruments[1,2]			
Betas	Scintillation counter	Pancake GM[3]	End Window GM[3]
^{3}H, ^{55}Fe, ^{63}Ni	50 %	NOT APPLICABLE	NOT APPLICABLE
^{14}C, ^{35}S	90 %	2 %	1 %
^{33}P, ^{45}Ca	90 %	15 %	10 %
^{32}P, ^{36}Cl, ^{86}Rb	100 %	35 %	20 %
Photons		NaI (Thin)	Gamma counter
^{109}Cd, ^{125}I		45 %	60 %
^{22}Na, ^{51}Cr, ^{65}Zn, ^{111}In, ^{131}I, ^{46}Sc, ^{95}Nb, ^{103}Ru, ^{113}Sn, ^{141}Ce		30 %	Unit specific

1 Specific efficiency data may be determined for the specific instruments and nuclides in use in a particular laboratory. That information may be used on survey records.

2 Efficiency may be reduced if the emission rate from a particular radionuclide is less than 100 %.

3 (Detector window 1 cm above source)

Action Levels

Evaluate contamination removed and take action as follows:

Action Levels for Removable Surface Contamination in Radiation Laboratories

'Clean areas' - bench tops, floors, freezers, refrigerators, desks, etc

<220 dpm	Acceptable level
≥ 220 dpm but < 2200 dpm	Decontamination recommended
≥ 2200 dpm	Decontamination **required**

Radiation labeled equipment--rad sinks, centrifuges, fume hoods, waste cans, etc

< 2200 dpm	Acceptable level
≥ 2200 dpm but < 22,000 dpm	Decontamination recommended
≥ 22,000 dpm	Decontamination **required**

Documentation and record keeping

The survey form used to document laboratory surveys must contain the following information:

Location, date of survey, name of individual performing the survey, isotopes in use, survey instrument(s) used, room layout drawing, counting equipment used, efficiency of counting equipment, results of surveys, notation as to corrective actions taken.

The survey forms may be patterned after the Radiation Safety Office laboratory survey form. An acceptable generic form is included in Appendix A. Complete all information requested on the form. Sign and date the form.

For weeks when no use of radioactive materials occurs, an entry should be made on the master calendar sheet that no survey is required that week.

File the completed forms in a file folder or loose leaf binder. The survey reports are subject to review by RSO and DEP personnel.

Survey reports must be retained for two years.

Common use or shared laboratories

For laboratories which are used by multiple Authorized Users, the responsibility for performing the weekly survey should be given to a mutually agreed upon individual.

Availability of Training

The Radiation Safety Office will conduct training on how to perform proper surveys for any laboratory that requests it.

Laboratories authorized for the use of radioactive materials will be surveyed and audited periodically by Radiation Safety personnel to assure radiologically safe working conditions.

H. USE OF RADIOACTIVE MATERIALS IN ANIMALS

The use of radioactive material in animals requires protocol approval from the IACUC and observance of Radiation Safety Office guidelines.

If the study is an acute study, it may be allowed to be performed in the research laboratory. It is the responsibility of the Authorized User to make certain his or her associates and employees understand and exercise the necessary safety precautions, handling procedures, clean up responsibilities, and waste disposal methods.

If the study requires use of radiolabeled animals in institutionally managed facilities, then the responsibility for animal care may be shared between the investigator and animal facility personnel. This division of responsibility must be developed co-operatively, before the study begins.

The following are some guidelines for the use of radioactive materials in animals:

1. The administration of radioactive materials to/into animals and the subsequent dissection of those animals should be performed in trays lined with absorbent padding.

2. Cages that house animals containing radioactive materials should be labeled with the name of the radionuclide, activity per animal, date of administration, and Authorized User's name.

3. Volatile and readily dispersible radioactive material should be administered in a fume hood. Subsequent work with the animal may also be best handled within the fume hood.

4. Animal carcasses and tissues containing radioactive material should be placed in a yellow plastic bag. Do not include any other materials such as pads, tubing, needles, instruments, etc. with the carcass. The bags can then be taken to a radioactive waste storage area during scheduled hours or by special arrangement. Radioactive animals and tissues should be kept refrigerated or frozen before delivery to Radiation Safety personnel.

5. Animal excreta may be disposed of through the sanitary sewer in accordance with the applicable limits for liquid waste (30 uCi/day).

6. Any material returned to the institutional animal care facility, such as cages, must be decontaminated prior to return.

I. PERSONNEL RADIATION MONITORING REQUIREMENTS

External Monitoring

The following table summarizes the various types of radiation work performed under the University of Pittsburgh licenses. For each type of work, the type of monitoring (if any) is indicated.

For radioisotope users, dosimetry is required for the handling of material in quantities equal to or greater than the indicated activity. For example, a radiation worker handling 5 mCi or more of Cr-51 is required to wear both ring and whole body dosimeters; however, a worker handling less than 5 mCi is not required to wear dosimetry. It is also required that all workers who have been issued dosimetry wear it at all times when handling isotopes, regardless of the activity level.

Type of Radiation Work	Activity level for Ring Badge	Activity level for Whole Body Badge
1) Radioisotopes (For isotopes not listed, contact RSO for guidance)		
Photon Emitters		
Group 1 - Na-22, Sc-46, Fe-59, Co-60, Sr-85, Nb-95	1 mCi	5 mCi
Group 2 - Cr-51, Co-57, I-125, I-131, Ce-141, In-111	5 mCi	5 mCi
Beta Emitters		
Emax $\geq$ 500 Kev P-32, Cl-36, Rb-86	1 mCi	5 mCi
Emax < 500 Kev H-3, C-14, S-35, Ca-45, Ni-63, P-33	Not required	Not required
2) Sealed sources or gamma irradiators	As required by RSO	As required by RSO
3) Analytical x-ray equipment	yes	As required by RSO
4) Clinical or research x-ray equipment	As required by RSO	yes
5) Particle accelerator	As required by RSO	yes

Internal Monitoring

Bioassays will be conducted for personnel handling or processing unsealed sources of radioactive material in excess of the amounts stated in the DEP license documentation. In addition, bioassays will be conducted when deemed necessary, such as part of investigations into accidental releases. Individuals involved in uses which require bioassay will be informed of the specific requirements by the RSO.

J. AIR SAMPLING AND POST-EXPERIMENTAL PROCEDURE SURVEYS

Air monitoring is required to be performed during experiments involving volatile radioactive compounds in quantities requiring bioassay in order to assure that concentrations of radioactivity in workplace air or released air do not present an exposure hazard or exceed legal limits. Arrangements for air sampling must be made with the RSO.

Post procedure contamination surveys are required following experiments utilizing quantities of radioactive materials which require a bioassay in order to assure that contamination has not been spread over the work area. Surveys should be documented and filed with regular laboratory surveys for review by RSO staff.

The following table summarizes the conditions under which air monitoring and/or post-experimental procedure surveys are required:

TABLE 11: CRITERIA FOR AIR MONITORING AND POST PROCEDURE SURVEYS

Radioactive material use	Air monitoring	Post-procedure survey
Labeling procedure using $\geq$ 1 mCi of a radioiodine compound	Yes	Yes
Procedure using $\geq$ 2.5 ALI* of any volatile radionuclide	Yes	Yes
Procedure using $\geq$ 25 ALI* of a non-volatile radionuclide compound	No	Yes

* ALI values are listed in Appendix C.

K. SCINTILLATION COUNTING

Only biodegradable or environmentally safe scintillation cocktails may be used, unless a special exemption is granted by the Radiation Safety Office. A list of acceptable cocktails is available from the RSO.

Plastic vials must be used unless a special exemption is granted by the Radiation Safety Office.

L. PREGNANT RADIATION WORKER POLICY:

Title: **Limits on Occupational Radiation Exposure to Employees Who Are Pregnant or Breast Feeding**

Background: Exposure of the embryo/fetus to ionizing radiation carries a risk of causing certain adverse health effects such as cancer and developmental abnormalities. Accordingly, the National Council on Radiation Protection and Measurement (NCRP) has recommended that the total dose equivalent to the embryo/fetus from occupational exposure of the expectant mother not exceed 500 mRem (NCRP Report No. 53), and that once the pregnancy is known, exposure of the embryo/fetus not exceed 50 mRem in any month (NCRP No. 91). The Nuclear Regulatory Commission (NRC) requires (in revised 10 CFR 20.1208) that the dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, not exceed 500 mRem, and that substantial variations in a uniform monthly exposure rate to satisfy this limit be avoided. The dose to the embryo/fetus is taken as the sum of the external deep dose equivalent to the pregnant woman and the dose from radionuclides incorporated in the embryo/fetus and pregnant woman.

In support of the NCRP recommendations and NRC regulations, the University of Pittsburgh's Radiation Safety Committee has instituted the following policy and guidelines for occupational radiation exposure of employees who are pregnant or breast-feeding.

Policy: The dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, will be limited to 500 mRem. Substantial variations in a uniform monthly exposure rate should be avoided. Limits of exposure to the general population will be applied to a nursing infant. Work restrictions may be required in order to meet the intent of this policy.

Procedure: A radiation worker who becomes pregnant should notify her department head or supervisor as early as possible. If the employee chooses not to declare the pregnancy to the Radiation Safety Office, additional controls and monitoring for her radiation exposure cannot be implemented.

Declarations of pregnancy must be made in writing and submitted to the Radiation Safety Office.

Upon notification of pregnancy, the RSO will provide instruction on the risks of radiation exposure to the embryo/fetus and review NRC Regulatory Guide 8.13 "Instruction Concerning Prenatal Radiation Exposure". The RSO will also evaluate the employee's radiation work environment, past exposure history and potential for future exposure. Based on this information, the RSO may make recommendations or impose restrictions regarding the employee's duties involving occupational radiation exposure. This review and evaluation will be documented, signed by the employee, the employee's department head or supervisor, the Radiation Safety Officer, and be filed in the RSO.

The pregnant employee may continue working in those areas and job duties where it is unlikely that her external and internal radiation exposures will exceed the total and monthly limits to the embryo/fetus, with proper attention to safe radiation practices. A pregnant employee will be restricted from those areas and job duties where there is potential for a significant radiation dose to the embryo/fetus from either an external or internal exposure. Examples of these types of situations are, but not limited to: administration of radiopharmaceutical therapy or brachytherapy, caring for patients receiving radiopharmaceutical therapy or brachytherapy, and performing iodinations or working in a laboratory where radioactive iodine in a volatile form is being used.

Appropriate radiation monitoring will be provided if it is likely that the embryo/fetus might receive an external dose of more than 50 mRem during the entire pregnancy. Bioassay will be required to monitor internal exposures for workers handling unsealed sources of radioactive material, if it is likely that an intake of a radionuclide would exceed 1% of an Annual Limit on Intake (ALI) during the entire period of gestation. Records of the dose to the embryo/fetus will be maintained with the mother's radiation dose records.

If the total effective dose to the embryo/fetus of the declared pregnant woman exceeds 400 mRem, she will be restricted from any further work involving occupational radiation exposure for the remainder of the pregnancy.

An employee who is breast-feeding may be restricted from those areas and job duties were unsealed sources of volatile radioactive materials are used. Bioassay may be required to monitor internal exposures of nursing workers handling unsealed sources of radioactive material. Recommendations will be made, based on the bioassay results, to assure that the nursing infant does not receive a committed effective dose equivalent of more than 100 mRem.

M. RADIOACTIVE WASTE DISPOSAL PROCEDURES

Radioactive wastes are an unavoidable byproduct of any use of radioactive materials. Once produced these wastes must be disposed of in a manner which minimizes impacts on public health and safety. A wide variety of laws and regulations are in force at the federal, state and local level which dictate how wastes are to be packaged, processed or disposed. At the same time, these wastes must be disposed of in the most cost effective manner possible. The University of Pittsburgh remains responsible for all licensed radioactive materials until they have been properly processed, decayed or placed in a licensed permanent repository.

The following guidelines have been developed to facilitate safe and efficient processing of radioactive wastes generated by most users at the University. It is recognized that while these general procedures and waste

classifications will cover most situations, there will be exceptions and special cases. Should any questions arise as to specific disposal procedures, the Radiation Safety Office should be consulted.

1. WASTE MINIMIZATION

One of the most important steps to the safe handling and disposal of radioactive wastes is to minimize the amount and types of waste generated. This process begins with design of an experiment and includes how materials are ultimately used and ultimately disposed. In all cases the total activity of materials used in an experiment should be kept as allow as practical. The use of immunofluorescent, or stable isotope techniques in place of radiolabeled procedures are examples of total avoidance of radioactive waste production. The use of aqueous or "biodegradable" solvent systems in place of hazardous solvent systems eliminates the production of costly mixed wastes. The use of short-lived radionuclides reduces the volume of wastes which must ultimately be sent to a permanent waste facility. Finally where long-lived isotope use is unavoidable, a significant effort can be made to produce the smallest quantity of contaminated wastes practical.

2. WASTE DISPOSAL

With the exception of aqueous liquid wastes disposed to the sanitary sewer, and unless a written exemption has been granted by the RSO, all radioactive wastes must be disposed of by Radiation Safety Office personnel. It is the responsibility of the authorized user and individual laboratory personnel to properly package wastes and bring it to an approved rad waste handling site (see TABLE 12). The Radiation Safety Office will provide all routine packaging materials (bags, tags, jugs, absorbent.). Special materials such as sharps containers are to be provided by of the individual authorized user. All non-standard materials must be approved by the RSO prior to use.

3. WASTE STORAGE

All wastes should be stored in appropriate LABELED waste containers and SECURED to prevent inappropriate disposal. If temporary (bench top) containers such as beakers or plastic bags are to be used in the immediate work area, they should be emptied at the end of each day unless they are labeled and appropriately secured. Wastes should be routinely removed from the laboratory to one of the waste processing or storage areas (see TABLE 12).

Solid wastes should be stored in rigid containers with lids, lined with a yellow plastic bag. Where appropriate these containers should be of such a construction to provide shielding from unnecessary radiation exposures. The radiation safety office recommends that these containers be of "step-top" design. These containers are to be provided by the individual authorized user. A list of acceptable containers is available from the Radiation Safety Office. Waste containers should be surveyed frequently for contamination. Contaminated containers should be disposed of or decontaminated.

Liquid wastes should be stored in appropriate containers to minimize the chance of spillage. Liquid wastes should be promptly solidified or where appropriate, disposed to the sanitary sewer. If bulk liquids are to be held for storage a secondary container of adequate volume to contain all spilled liquids should be used. All containers should be labeled as radioactive waste. If appropriate, they should be of such a construction to provide shielding from unnecessary radiation exposures.

4. LABELING WASTES FOR DISPOSAL:

All wastes consigned to the Radiation Safety Office for disposal must be labeled with a radioactive waste tag. Labels are available from the Radiation Safety Office.

Each container of radioactive waste must have a properly completed radioactive waste tag affixed to it. All information must be legible, in indelible ink, and include:

- the isotope
- an accurate estimate of activity IN MILLICURIES

- the name of the authorized user
- the date the waste is prepared for disposal.
- the type of waste

5. SEGREGATION OF RADIOACTIVE WASTE

Segregation of wastes at the point of generation is an essential in the safe handling and disposal of radioactive wastes. Radioactive wastes within the University system can be broken down into six broad categories, each with specific disposal requirements:

Dry Solid Waste: Contaminated paper, plastic, and glass associated with radioactive materials work, residual solid radioactive materials, contaminated building debris etc...

Liquid Waste: Any non-hazardous liquid containing dissolved or suspended radioactive materials.

Scintillation Waste Vial, plates or bulk liquid wastes and other materials containing solutions used in liquid scintillation counting.

Biological Waste: Animal carcasses, blood, tissue samples, food wastes, solid or liquid excreta or other organic material not rendered resistant to decomposition.

Mixed Waste: Any wastes, solid or liquid which possess inherent hazards in addition to being radioactive, including listed hazardous chemicals, infectious or biohazardous materials.

Sealed Sources: Radioactive materials encapsulated, plated or otherwise incorporated into a solid support media used in association with an instrument or device.

In addition to segregation by waste class all wastes must also be segregated by isotope. An exception to this rule may be granted by the RSO, such as in the case of multiple label experiments.

Whenever possible high activity wastes, such as stock vials, should not be mixed with regular dry wastes and should be packaged separately. This is necessary to facilitate shielding and minimize storage and/or disposal volumes.

6. GENERAL LABORATORY GUIDELINES

All wastes should be stored in a labeled storage container appropriate for the specific waste stream.

Keep volumes as small as possible.

Place ONLY radioactive materials in the radioactive waste containers - mixing non-radioactive waste and radioactive wastes results in unnecessary increases in disposal costs.

NEVER use dry waste containers for free liquids, scintillation vials, biological animal carcasses, or lead wastes.

Wastes containing hazardous, biological, pathogenic or infectious material must be treated to reduce these potential hazards to the maximum extent practicable prior to disposal.

Wastes must not contain or be capable of generating gases, vapors, or fumes harmful to persons transporting, handling, or disposing of those wastes.

Wastes must not be pyrophoric. Wastes capable of igniting spontaneously must be treated and rendered non-flammable prior to disposal.

"Sharps", including but not limited to syringes, Pasteur pipettes, razor blades, scalpels and broken glass, must be packaged in a specifically designed sharps container.

Where possible, wastes containing low levels of ^{125}I should be limited to less than 10 microcuries per container.

When ^{14}C and ^{3}H are used in animals, whenever possible, restrict concentrations to less than 0.05 μCi/gram of animal tissue.

Dispose of radioactive waste in a timely fashion, i.e. at the end of a series of uses. Waste does not need to be kept until the bag is completely full.

7. SPECIFIC GUIDELINES

A. LIQUID WASTE

Any liquid, other than liquid scintillation fluids, containing dissolved or suspended radioactive materials constitutes liquid radioactive waste. Liquid wastes can be classified into three basic groups:

LOW LEVEL AQUEOUS/WATER SOLUBLE WASTES

Radioactive liquid wastes which are fully soluble or biologically dispersible in water may be discharged directly into the sanitary sewer system via a designated radiation sink drain. The permissible limit of disposal by this means is restricted to less than 100 microcuries per day of ^{3}H, and 30 microcuries per day of all other nuclides combined, averaged over a week. Alpha emitting nuclides are not permitted to be disposed of by this means. Sinks must be appropriately designated and labeled (one sink per laboratory).

Taking care to minimize splashing, pour the liquid waste directly into the drain with the water turned off. This should be followed immediately by a water flush with copious quantities of water. All disposal must be recorded on a sink log noting the date, isotope activity and the initials of the person disposing of the material. If total activities greater than the weekly limits are generated contact the Radiation Safety Office for special disposal directions.

HIGH LEVEL AQUEOUS/WATER SOLUBLE WASTES:

Aqueous or water soluble wastes excluded from sink disposal due to their activity or other characteristics, such as alpha emitters, must be solidified or absorbed with an approved media. Plastic jugs containing approved solidification media are available through the Radiation Safety Office. Once treated, these wastes should be placed in yellow plastic bags and labeled with the authorized user's name, the isotope, the estimated activity and the date of closure. (Treated liquid wastes may be disposed of with higher level dry solid wastes).

Never accumulate high level liquid wastes in the laboratory without appropriate containment and shielding.

NON-AQUEOUS WASTES (EPA - "MIXED WASTE")

Most non-aqueous liquid wastes are excluded from sink disposal due to their insolubility or other characteristics. They must be packaged in accordance with both DEP and EPA hazardous waste regulations. Specific disposal direction must be obtained from the Radiation Safety Office **PRIOR** to generating these types of waste.

B. DRY SOLID WASTE

Dry compactable radioactive wastes such as gloves, padding, paper, plastic and glass should be segregated according to isotope and placed into appropriate labeled waste containers lined with RSO approved yellow plastic bags. Whenever possible low level wastes such as paper wastes, gloves etc., should be kept separate from high level materials such as columns, gels and residual stock vials.

C. "SHARPS" WASTE

All broken glassware, needles, pipettes and other items which can penetrate the waste bags should be placed into a sharps container for disposal. These containers should then be placed into a yellow waste bag and appropriately

closed and labeled.

D. LEAD WASTE

Lead containers must be packaged separately from normal solid wastes. As with all radioactive wastes, these bags must be labeled clearly with a radioactive waste tag. Empty containers should be bagged with the lids or caps detached. Vials of radioactive material MAY be left in the lead container to provide shielding for any residual activity. The remaining activity must be clearly marked on the waste tag. If large lead objects such as contaminated shielding bricks are involved, please contact the Radiation Safety Office for instructions.

E. LIQUID SCINTILLATION WASTE

Vials, tubes or other containers used with or containing solutions used for liquid scintillation counting constitute liquid scintillation wastes. If available, scintillation vials should be repacked into the original cardboard trays or cartons. The RSO will accept a complete carton of trays if it is taped closed and a completed waste tag applied. Mini vials and bulk tubes should be placed into a yellow plastic bag.

RESEARCHERS MUST USE PLASTIC SCINTILLATION VIALS AND NON-HAZARDOUS BIODEGRADABLE SCINTILLATION MEDIA, UNLESS OTHERWISE SPECIFICALLY AUTHORIZED BY THE RADIATION SAFETY OFFICE.

SCINTILLATION WASTES ARE NOT TO BE DISPOSED OF BY POURING DOWN THE DRAIN.

SPECIAL DISPOSAL ARRANGEMENTS MUST BE MADE FOR GLASS VIALS, BULK LIQUIDS AND TOLUENE/XYLENE AND OTHER FLAMMABLE SOLVENT BASED WASTES.

F. BIOLOGICAL WASTE

The carcasses of research animals used with radioactive materials and any solid or liquid radioactive waste containing significant quantities of tissue or excreta are classified as biological wastes. These wastes require special handling and packaging in order to meet disposal criteria. As such they **MUST BE SEGREGATED** from other waste streams and properly identified

ANIMAL CARCASSES

The remains of experimental animals, organ or tissues to which radioactive materials have been administered should be placed into yellow plastic bags properly labeled and frozen immediately. These wastes are then to be transferred directly to a designated storage freezer, or to the waste processing areas attended by Radiation Safety personnel.

☺ When using ^{14}C and ^{3}H, whenever possible restrict concentrations to less than 0.05 μCi/gram of animal tissue. This facilitates disposal as *De Minimis* waste.

☹ The use of formaldehyde/formalin and other hazardous chemical agents must be restricted. These wastes constitute a mixed waste stream and are very difficult to dispose of. If these agents are to be used please contact the Radiation Safety Office for special packaging procedures.

☻ Blood, urine and other liquid biological wastes, not suitable for sanitary sewer disposal, must be adsorbed with an approved media or otherwise converted to solid form prior to disposal. These materials **MAY NOT** be disposed as regular dry solid or absorbed liquid waste.

☺ Ashed, freeze dried, or otherwise desiccated biological wastes may be disposed of as dry solid wastes only if liquids are excluded from the same package.

UNDER NO CIRCUMSTANCES ARE CARCASSES TO BE PLACED IN RAD WASTE DRUMS, OR STORED AT ROOM TEMPERATURE!!

OTHER BIOLOGICAL WASTES

Materials associated with animal or tissue work containing significant biological material must be treated as biological waste. This category of waste includes any material which will decompose at room temperature to release gasses, vapors or fumes which may be hazardous to personnel transporting or otherwise handling these materials.

TABLE 12: RADIOACTIVE WASTE PROCESSING AND STORAGE LOCATIONS

Location	Waste receipt
Biomedical Science Tower 3 Room 2023	Access key obtained through Dock Manager
Biomedical Science Tower BST Loading dock	Call RSO for Pickup
Bridgeside Point 1 Loading dock cabinet	Keys issued to individual users
Bridgeside Point 2 Room 201A	Card access
Eye and Ear Institute Use BST Loading Dock	Call RSO for Pickup
GSPH G033A	Card Access
Hillman Cancer Center Room G.7	Wed 10:00 am to 11:00 am
Langley Hall Parking Garage	Access key obtained through Biological Stock Room.
Magee Womens Hospital MWH Loading dock	Access key obtained through Safety and Security Department
Magee Womens Research Institute Room 100	Access with building key
Montefiore University Hospital Room N-307	Access key available on each research floor
Rangos Research Center Room 3528	Access Keys issued to Individual Users or available from research administration
Salk Hall Room 222B	Access Key obtained through Receiving Dept, Room 224
Salk Pavilion	Card Access
Scaife Hall Loading dock, Vault A	Tues 10:00 am to 11:00 pm
WPIC Room E-110A	Access key obtained through purchasing office

FOR FACILITIES NOT LISTED ABOVE CONTACT RSO FOR INSTRUCTION REGARDING WASTE DISPOSAL

Revised 7/17

APPENDICES

APPENDIX A

LABORATORY SURVEY PROGRAM FORMS WITH GUIDELINES

LAB SURVEY REPORT **LOCATION:** **AUTH. USER:**

ISOTOPES IN USE:

SMEAR #	LOCATION	METER cpm	SMEAR Net dpm	RESURVEY
	BACKGROUND			
	RED BAG TRASH			
	"COLD" TRASH			

SURVEY METER: **EFFICIENCY:**
SCINTILLATION/GAMMA COUNTER: **EFFICIENCY:**

DECONTAMINATION AND RESURVEY REQUIRED IF LEVELS EXCEED:

Radiation equipment: **2200 dpm removable contamination**
All other areas: **220 dpm removable contamination**
Clean & red bag trash: **No detectable meter readings**

SURVEYED BY: _____ DATE: _____

RETAIN THIS RECORD FOR RSO INSPECTION

C:\WP51\FORMS\LABSVY

2018 LABORATORY SURVEY MASTER CALENDAR LOCATION:

WEEK BEGINNING	SURVEY DATE	MATERIAL USED		METER SURVEY	WIPE SURVEY	INIT	RSO AUDIT
		YES	NO				
12/25/17							
1/1/18							
1/8/18							
1/15/18							
1/22/18							
1/29/18							
2/5/18							
2/12/18							
2/19/18							
2/26/18							
3/5/18							
3/12/18							
3/19/18							
3/26/18							
4/2/18							
4/9/18							
4/16/18							
4/23/18							
4/30/18							
5/7/18							
5/14/18							
5/21/18							
5/28/18							
6/4/18							
6/11/18							
6/18/18							
6/25/18							
7/2/18							
7/9/18							
7/16/18							
7/23/18							
7/30/18							
8/6/18							
8/13/18							
8/20/18							
8/27/18							
9/3/18							
9/10/18							
9/17/18							
9/24/18							
10/1/18							
10/8/18							
10/15/18							
10/22/18							
10/29/18							
11/5/18							
11/12/18							
11/19/18							
11/26/18							
12/3/18							
12/10/18							
12/17/18							

Guidelines for Completion of Laboratory Survey Report

1. Master Calendar page

   This page is designed for use as a weekly reminder/checklist. It may be posted or retained with the individual survey reports. Multiple sheets should be used if multiple laboratories are surveyed.

   Explanation of each column:

"Week beginning":	The Sunday date is shown
"Survey Date":	Record the actual date each survey is done.
"Material Used":	Indicate with check mark whether radioactive material was used that week
"Meter Survey":	Indicate with check mark whether a meter survey was done that week
"Wipe survey":	Indicate with check mark whether a smear survey was done that week
"Init":	Initials of the individual completing this page
"RSO Audit":	To be filled out by representatives of the Radiation Safety Office

2. Preparing a master form for a specific laboratory

   The following items may be filled in before duplication for weekly use:

   Location
   Auth User name
   Room layout diagram (Note you may not wish to number items until the survey is actually performed)
   Survey meter used (if same each week)
   Efficiency for above
   Scintillation/gamma counter used (if same each week)
   Efficiency for above

   DO NOT SIGN THE MASTER FORM IN THE "SURVEYED BY" LINE--Each survey should be signed at the time it is performed.

3. Efficiency of counting instruments

   Table 1 shows acceptable efficiency factors for specific radionuclides. You may use these factors, or determine your own.

TABLE 1
Average Counting Efficiency for Standard Instruments[1,2]

Betas	LSC	PANCAKE GM[3]	END WINDOW GM[3]
^{3}H, ^{55}Fe, ^{63}Ni	50 %	NOT APPLICABLE	NOT APPLICABLE
^{14}C, ^{35}S	90 %	2 %	1 %
^{33}P, ^{45}Ca	90 %	15 %	10 %
^{32}P, ^{36}Cl, ^{86}Rb	100 %	35 %	20 %
Photons		NaI (Thin)	Gamma counter
Low energy ^{109}Cd, ^{125}I		45 %	60 %
Medium and high energy ^{22}Na, ^{51}Cr, ^{65}Zn, ^{111}In, ^{131}I, ^{46}Sc, ^{95}Nb, ^{103}Ru, 113Sn, 141Ce		30 %	Unit specific

[1] Specific efficiency data may be determined for the specific instruments and nuclides in use in a particular laboratory. That information may be used on survey records.
[2] Efficiency may be reduced if the emission rate from a particular radionuclide is less than 100%.
[3] (Detector window 1 cm above source)

4. Use of scintillation or gamma counters

Pay particular attention to the counting program used. Verify that the program you use actually has the energy ranges set for the radionuclide(s) that you use. Each time you use the counter, verify that the program has not been changed (Look at counting time, window settings (energy range) selected, efficiency factors applied).

IF PRINTOUTS ARE IN "DPM", you may attach them to the survey report. Otherwise, convert the "CPM" readings to dpm and record on the survey form.

5. Conversion of CPM to DPM

Contamination should be reported in units of activity (DPM). This is different than CPM which is the number of electronic pulses recorded by the instrument. The conversion factor is a function of the type of detector, the counting configuration, and other factors.

The amount of radioactivity that has been detected by direct monitoring or by wipe survey can be readily estimated by subtracting the background count rate (bkg counts/min) from the observed count rate (gross counts/min) and then dividing the net count rate by the counting efficiency (counts/disintegration) for the radionuclide in question.

$$\text{net disintegrations/min(dpm)} = \frac{\text{(gross cpm)-(bkg cpm)}}{\text{efficiency}}$$

An example of this calculation follows:

Assume one minute counts

Background counts = 55 Sample counts = 470 Efficiency = 0.15

Net DPM = (Sample counts - Background counts)/Efficiency

= (470-55)/0.15

= 2767 dpm At this level, decontamination is recommended.

APPENDIX B

NRC REGULATORY GUIDE 8.13

U.S. NUCLEAR REGULATORY COMMISSION
REGULATORY GUIDE
OFFICE OF NUCLEAR REGULATORY RESEARCH
REGULATORY GUIDE 8.13
(Task OP 031-4)
INSTRUCTION CONCERNING PRENATAL RADIATION EXPOSURE

A. INTRODUCTION

Section 19.12, "Instructions to Workers," of 10 CFR Part 19, "Notices, Instructions, and Reports to Workers: Inspections," requires that all individuals working in or Frequenting any portion of a restricted area[1] be instructed in the health protection problems associated with exposure to radioactive materials or radiation, in precautions or procedures to minimize exposure, and in the regulations that they are expected to observe. The present 10 CFR Part 20, "Standards for Protection Against Radiation," has no special limit for exposure of the embryo/fetus.[2] This guide describes the instructions an employer should provide to workers and supervisors concerning biological risks to the embryo/fetus exposed to radiation, a dose limit for the embryo/fetus that is under consideration, and suggestions for reducing radiation exposure.

This regulatory guide takes into consideration a proposed revision to 10 CFR Part 20, which incorporates the radiation protection guidance for the embryo/fetus approved by the President in January 1987 (Ref.1). This revision to Part 20 was issued in January 1986 for comment as a proposed rule. Comments on the guide as it pertains to the proposed part 20 are encouraged. If the new Part 20 is codified, this regulatory guide will be revised to conform to the new regulation and will incorporate appropriate public comments.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Parts 19 or 20, which provide the regulatory basis for this guide. The information collection requirements in 10 CFR Parts 19 and 20 have been cleared under OMB Clearance Nos. 3150-0044 and 3150-0014, respectively.

B. DISCUSSION

It has been known since 1906 that cells that are dividing very rapidly and are undifferentiated in their structure and function are generally more sensitive to radiation. In the embryo stage, cells meet both these criteria and thus would be expected to be highly sensitive to radiation. Furthermore, there is direct evidence that the embryo/fetus is radiosensitive. There is also evidence that it is especially sensitive to certain radiation effects during certain periods after conception, particularly during the first 2 to 3 months after conception when a women may not be aware that she is pregnant.

Section 20.104 of 10 CFR Part 20 places different radiation dose limits on workers who are minors than on adult workers. Workers under the age of 18 are limited to one-tenth of the adult radiation dose limits. However, the present NRC regulations do not establish dose limits specifically for the embryo/fetus.
The NRC's present limit on radiation dose that can be received on the job is 1,250 millirems per quarter (3 months) [1]. Working minors (those under 18) are limited to a dose equal to one-tenth that of adults, 125 millirems per quarter (See 20.101 of 10 CFR Part 20).

Because of the sensitivity of the unborn child, the National Council on Radiation Protection and Managements (NRCP) has recommended that the dose equivalent to the unborn child from occupational exposure of the mother be limited to 500 millirems for the entire pregnancy (Ref. 2). The 1987 Presidential guidance (Ref. 1) specifies an effective dose equivalent of 500 millirems to the unborn child if the pregnancy has been declared by the mother; the guidance also recommends that the substantial variations in the rate of exposure be avoided. The NRC (in 20.208 of its proposed revision of Part 20) has proposed adoption of the above limits on the dose and rate of exposure.

In 1971, the NCRP commented on the occupational exposure of the fertile women (Ref. 2) and suggested that fertile women should be employed only where the annual dose would be unlikely to exceed 2 or 3 rems and would be accumulated at a more or less steady rate. In 1977, the ICRP recommended that, when pregnancy has been diagnosed, the woman work only where it is unlikely that the annual dose would exceed 0.30 of the dose-equivalent limit of 5 rems (Ref. 3). In other words, the ICRP has recommended that pregnant women no work where the annual dose might exceed 1.5 rem.

[1] Restricted area means any area that has controlled access to protect individuals from being exposed to radiation and radioactive materials.

[2] In conformity with the proposed revision to 10 CFR Part 20, the term "embryo/fetus" is used throughout this document to represent all stages of pregnancy.

[3] The limit is 3,000 millirems per quarter if the worker's occupational dose history is known and the average dose does not exceed 5,000 millirems per year.

C. REGULATORY POSITION

Instructions on radiation risks should be provided to workers, including supervisors, in accordance with 19.12 of 10 CFR Part 19 before they are allowed to work in a restricted area. In providing instructions on radiation risks, employers should include specific instructions about the risks of radiation exposure to the embryo/fetus.

The instructions should be presented both orally and in printed form, and the instructions should include, as a minimum, the information provided in Appendix A (Instructor's Guide) to this guide. Individuals should be given the opportunity to ask questions and in turn should be questioned to determine whether they understand the instructions. An acceptable method of ensuring that the information is understood is to give a simple written test covering the material included in Appendix B (Pregnant Worker's Guide). This approach should highlight for instructors those parts of the instructions that cause difficulties and thereby lead to appropriate modifications in the instructional curriculum.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which an applicant or licensee purposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the NRC will use the material described in this guide to evaluate the instructional program presented to individuals, including supervisors, working in or frequenting any portion of a restricted area.

APPENDIX A
INSTRUCTOR'S GUIDE
EFFECTS ON THE EMBRYO/FETUS OF EXPOSURE TO RADIATION AND OTHER ENVIRONMENTAL HAZARDS

In order to decide whether to continue working while exposed to ionizing radiation during her pregnancy, a woman should understand the potential effects on an embryo/fetus, including those that may be produced by various environmental risks such as smoking and drinking. This will allow her to compare these risks with those produced by exposure to ionizing radiation.

Table 1 provides information on the potential effects resulting from exposure of an embryo/fetus to radiation and nonradiation risks. The second column gives the rate at which the effect is produced by natural causes in terms of the number per thousand cases. The fourth column gives the number of additional effects per thousand cases believed to be produced by exposure to the specified amount of the risk factor.

The following section discusses the studies from which the information in Table 1 was derived. The results of exposure of the embryo/fetus to the risk factors and the dependence on the amount of the exposure are explained.

2. RADIATION RISKS

1.1 Childhood Cancer

Numerous studies of radiation-induced childhood cancer have been performed, but a number of them are controversial. The National Academy of Science (NAS) BEIR report reevaluated the data from these studies and even reanalyzed the results. Some of the strongest support for a causal relationship is provided by twin data from the Oxford survey (Ref. 4). For maternal radiation doses of 1,000 millirems, the excess number of deaths (above those occurring from natural causes) was found to be 0.6 death per thousand children (Ref. 4).

1.2 Mental Retardation and Abnormal Smallness of Head (Microcephaly)

Studies of Japanese children who were exposed while in the womb to the atomic bomb radiation at Hiroshima and Nagasaki have shown evidence of both small head size and mental retardation. Most of the children were exposed to radiation doses in the range of 1 to 50 rads. The importance of the most recent study lies in the fact that investigators were able to show that the gestational age (age of the embryo/fetus after conception) at the time the children were exposed was a critical factor (Ref. 7). The approximate risk of small head size as a function of gestational age is shown in Table 1. For a radiation dose of 1,000 millirems at 4 to 7 weeks after conception, the excess cases of small head size was 5 per thousand; at 8 to 11 weeks, it was 9 per thousand (Ref. 7).

In another study, the highest risk of mental retardation occurred during the 8 to 15 week period after conception (Ref. 8). A recent EPA study (Ref. 16) has calculated that excess cases of mental retardation per live birth lie between 0.5 and 4 per thousand per rad.

1.3 Genetic Effects

Radiation-induced genetic effects have not been observed to date in humans. The largest source of material for genetic studies involves the survivors of Hiroshima and Nagasaki, but the 77,000 births that occurred among the survivors showed no evidence of genetic effects. For doses received by the pregnant worker in the course of employment considered in this guide, the dose received by the embryo/fetus apparently would have a negligible effect on descendants (Refs. 17 and 18).

2. NON-RADIATION RISKS

2.1 Occupation

A recent study (Ref. 9) involving the birth records of 130,000 children in the State of Washington indicates that

the risk of death to the unborn child is related to the occupation of the mother. Workers in the metal industry, the chemical industry, medical technology, the wood industry, the textile industry, and farms exhibited stillbirths or spontaneous abortions at a rate of 90 per thousand above that of workers in the control group, which consisted of workers in several other industries.

2.2 Alcohol

It has been recognized since ancient times that alcohol consumption had an effect on the unborn child. Carthaginian law forbade the consumption of wine on the wedding night so that a defective child might not be conceived. Recent studies have indicated that small amounts of alcohol consumption have only the minor effect of reducing the birth weight slightly, but when consumption increases to 2 to 4 drinks per day, a pattern of abnormalities called the fetal alcohol syndrome (FAS) begins to appear (Ref. 11). This syndrome consists of reduced growth in the unborn child, faulty brain function, and abnormal facial features. There is a syndrome that has the same symptoms as full-blown FAS that occurs in children born to mothers who have not consumed alcohol. This naturally occurring syndrome occurs in about 1 to 2 cases per thousand (Ref. 10). For mothers who consume 2 to 4 drinks per day, the excess occurrences number about 100 per thousand; and for those who consume more than 4 drinks per day, excess occurrences number 200 per thousand. The most sensitive period for this effect of alcohol appears to be the first few weeks after conception, before the mother-to-be realizes she is pregnant (Refs. 10 and 11). Also, 17% or 170 per thousand of the embryo/fetuses of chronic alcoholics develop FAS and die before birth (Ref. 15). FAS was first identified in 1973 in the United States where less than full-blown effects of the syndrome are now referred to as fetal alcohol effects (FAE) (Ref. 12).

2.3 Smoking

Smoking during pregnancy causes reduced birth weights in babies amounting to 5 to 9 ounces on the average. In addition, there is an increased risk of 5 infant deaths per thousand for mothers who smoke less than one pack per day and 10 infant deaths per thousand for mothers who smoke one or more packs per day (Ref. 13).

2.4 Miscellaneous

Numerous other risks affect the embryo/fetus, only a few of which are touched upon here. Most people are familiar with the drug thalidomide (a sedative given to some pregnant women), which causes children to be born with missing limbs, and the more recent use of the drug diethylstilbestrol (DES), a synthetic estrogen given to some women to treat menstrual disorders, which produced vaginal cancers in the daughters born to women who took the drug. Living at high altitudes also gives rise to an increase in the number of low-birth-weight children born, while an increase in Down's syndrome (Mongolism) occurs in children born to mothers who are over 35 years of age. The rapid growth in the use of ultrasound in recent years has sparked an ongoing investigation into the risks of using ultrasound for diagnostic procedures (Ref. 19).

TABLE 1
EFFECTS OF RISKS FACTORS ON PREGNANCY OUTCOME

EFFECT	NUMBER OCCURRING FROM NATURAL CAUSES	RISK FACTOR	EXCESS OCCURRENCES FROM RISK FACTOR
		RADIATION RISKS	
		Childhood Cancer	
Cancer death in children	1.4 per thousand (Ref. 5)	Radiation dose of 1000 millirems received before birth	0.6 per thousand (Ref. 4)
		Abnormalities	
		Radiation dose of 1000 millirads received during specific periods after conception:	
Small head size	40 per thousand (Ref. 6)	4-7 weeks after conception	5 per thousand (Ref. 7)
Small head size	40 per thousand (Ref. 6)	8-11 weeks after conception	9 per thousand (Ref. 7)
Mental retardation	4 per thousand (Ref. 8)	Radiation dose of 1000 millirads received 8 to 15 weeks after conception	4 per thousand (Ref. 8)
		Non-Radiation Risks	
		Occupation	
Stillbirth or spontaneous abortion	200 per thousand (Ref. 9)	Work in high-risk occupations (see text)	90 per thousand (Ref. 9)
		Alcohol Consumption (see text)	
Fetal alcohol syndrome	1 to 2 per thousand (Ref. 10)	2-4 drinks per day	100 per thousand (Ref. 11)
Fetal alcohol syndrome	1 to 2 per thousand (Ref. 10)	More than 4 drinks per day	200 per thousand (Ref. 11)
Fetal alcohol syndrome	1 to 2 per thousand (Ref. 10)	Chronic alcoholic (more than 10 drinks per day)	350 per thousand (Ref. 12)
Perinatal infant death (around the time of birth)	23 per thousand (Refs. 13, 14)	Chronic alcoholic (more than 10 drinks per day)	170 per thousand (Ref. 15)
		Smoking	
Perinatal infant death	23 per thousand (Refs. 13, 14)	Less than 1 pack per day	5 per thousand (Ref. 13)
Perinatal infant death	23 per thousand (Refs. 13, 14)	One pack or more per day	10 per thousand (Ref. 13)

APPENDIX B
PREGNANT WORKER'S GUIDE
POSSIBLE HEALTH RISKS TO CHILDREN OF WOMEN WHO ARE EXPOSED TO RADIATION DURING PREGNANCY

During pregnancy, you should be aware of things in your surroundings or your style of life that could affect your unborn child. For those of you who work in or visit areas designated as Restricted Areas (where access is controlled to protect individuals from being exposed to radiation and radioactive materials), it is desirable that you understand the biological risks of radiation to your unborn child.

Everyone is exposed daily to various kinds of radiation: Heat, light, ultraviolet, microwave, ionizing, and so on. For the purposes of this guide only ionizing radiation (such as x-rays, gamma rays, neutrons, and other high-speed atomic particles) is considered. Actually, everything is radioactive and all human activities involve exposure to radiation. People are exposed to different amounts of natural "background" ionizing radiation depending on where they live. Radon gas in homes is a problem of growing concern. Background radiation comes from three sources:

	Average Annual Dose
Terrestrial - radiation from soil And rocks	50 mRem
Cosmic - radiation from space	50 mRem
Radioactivity normally found Within the human body	25 mRem
	125 mRem*

Dosage range (geographic and other factors) 75 to 5,000 millirem

The first two of these sources expose the body from the outside, and the last one exposes it from the inside. The average person is thus exposed to a total dose of about 125 millirems per year from natural background radiation.

- Radiation doses in this document are described in two different units. The rad is a measure of the amount of energy absorbed in a certain amount of material (100 ergs per gram). Equal amounts of energy absorbed from different types of radiation may lead to different biological effects. The rem is a unit that reflects the biological damage done to the body. The millirad and millirem refer to 1/1000 of a rad and a rem, respectively

In addition to exposure from normal background radiation, medical procedures may contribute to the dose people receive. The following table lists the average doses received by the bone marrow (the blood-forming cells) from different medical applications.

X-Ray Procedure	Average Dose*
Normal chest examination	10 millirem
Normal dental examination	10 millirem
Rib cage examination	140 millirem
Gall bladder examination	170 millirem
Barium enema examination	500 millirem
Pelvic examination	600 millirem

*Variations by a factor of 2 (above and below) are not unusual.

NRC POSITION

NRC regulations and guidance are based on the conservative assumption that any amount of radiation, no matter how small, can have a harmful effect on an adult, child, or unborn child. This assumption is said to be conservative because there are no data showing ill effects from small doses; the National Academy of Sciences recently expressed "uncertainty as to whether a dose of, say, 1 rad would have any effect at all." Although it is known that the unborn child is more sensitive to radiation than adults, particularly during certain stages of development, the NRC has not established a special dose limit for protection of the unborn child. Such a limit could result in job discrimination for women of child-bearing age and perhaps in the invasion of privacy (if pregnancy tests were required) if a separate regulatory dose limit were specified for the unborn child. Therefore, the NRC has taken the position that special protection of the unborn child should be voluntary and should be based on decisions made by workers and employers who are well informed about the risks involved.

For the NRC position to be effective, it is important that both employee and the employer understand the risk to the unborn child from radiation received as a

result of the occupational exposure of the mother. This document tries to explain the risk as clearly as possible and to compare it with other risks to the unborn child during pregnancy. It is hoped this will help pregnant employees balance the risk to the unborn child against the benefits of employment to decide if the risk is worth taking. This document also discusses methods of keeping the dose, and therefore the risk, to the unborn child as low as is reasonably achievable.

RADIATION DOSE LIMITS

The NRC's present limit on the radiation dose that can be received on the job is 1, 250 millirems per quarter (3 months).* Working minors (those under 18) are limited to a dose equal to one-tenth that of adults, 125 millirems per quarter. (See 20.101 of 10 CFR Part 20).

Because of the sensitivity of the unborn child, the National Council on Radiation Protection and Measurements (NCRP) has recommended that the dose equivalent to the unborn child from occupational exposure of the expectant mother be limited to 500 millirems for the entire pregnancy (Ref. 2). The 1987 Presidential guidance (Ref. 1) specifies an effective dose equivalent limit of 500 millirems to the unborn child if the pregnancy has been declared by the mother; the guidance also recommends that substantial variations in the rate of exposure be avoided. The NRC (in 20.208 of its proposed revision to Part 20) has proposed adoption of the above limits on dose and rate of exposure.

ADVICE FOR EMPLOYEE AND EMPLOYER

Although the risks to the unborn child are small under normal working conditions, it is still advisable to limit the radiation dose from occupational exposure to no more that than 500 millirems for the total pregnancy. Employee and employer should work together to decide the best method for accomplishing this goal. Some methods that might be used include reducing the time spent in radiation areas, wearing some shielding over the abdominal area, and keeping an extra distance from radiation sources when possible. The employer or health physicist will be able to estimate the probable dose to the unborn child during the normal nine month pregnancy period and to inform the employee of the amount. If the predicted dose excess 500 millirem, the employee and employer should work out schedules or procedures to limit the dose to the 500-millirem recommended limit.

It is important that the employee inform the employer of her condition as soon as she realizes she is pregnant if the dose to the unborn child is to be minimized.

INTERNAL HAZARDS

The document has been directed primarily toward a discussion of radiation doses received from sources outside the body. Workers should also be aware that there is a risk of radioactive material entering the body in workplaces where unsealed radioactive material issued. Nuclear medicine clinics, laboratories, and certain manufacturers use radioactive material in bulk form, often as a liquid or a gas. A list of the commonly used materials and safety precautions for each is beyond the scope of this document, but certain general precautions might include the following:

- Do not smoke, eat, drink, or apply cosmetics around radioactive material.
- Do not pipette solutions by mouth.
- Use disposable gloves while handling radioactive material when feasible.
- Wash hands after working around radioactive material.
- Wear laboratory coats or other protective clothing whenever there is a possibility of spills.

Remember that the employer is required to have demonstrated that it will have safe procedures and practices before the NRC issues it a license to use radioactive material. Workers are urged to follow established procedures and consult the employer's radiation safety officer or health physicist whenever problems or questions arise.

VALUE/IMPACT STATEMENT

A draft value/impact statement was published with the proposed Revision 2 to Regulatory Guide 8.13 (Task OP 031-4) when the draft guide was published for public comment in August 1981. No changes were necessary, so a separate value/impact statement for the final guide has not been prepared. A copy of the draft value/impact statement is available for inspection and copying for a fee at the Commission's Public Document Room at 1717 H Street NW., Washington DC, under Task OP 031-4.

* The limit is 3,000 millirems per quarter if the worker's occupational dose history is known and the average dose does not exceed 5,000 millirems per year.

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APPENDIX C

INFORMATION FOR SPECIFIC RADIONUCLIDES

Table of ALI* values in mCi

	2.5 ALI	25 ALI
C-14	Na	50
Ca-45	Na	50
Cd-109	Na	7.5
Ce-141	Na	50
Cl-36	Na	50
Cr-51	Na	1000
Fe-55	Na	225
H-3	200	2000
I-125	0.1	1
I-131	0.075	0.75
In-111	Na	100
Na-22	Na	10
Nb-95	Na	50
P-32	Na	15
P-33	Na	150
Rb-86	Na	12.5
Ru-103	Na	50
S-35	25	250
Sc-46	Na	22.5
Sn-113	Na	50
Sr-85	Na	75
Tc-99m	Na	2000
Zn-65	Na	10

* ALI (Annual Limit on Intake) is the derived annual limit for the amount of radioactive material taken into the body by inhalation or ingestion, which would result in the annual allowable occupational dose for that year.

Cd-109	CADMIUM	^{109}Cd
Half-life:	464 days	
Type of Decay:	Electron Capture	
Energy of Radiation:	0.088 MeV (Ag-109m)	0.062 MeV 0.084 MeV (e^-)
Lead Shielding HVL:	0.8 mm	0.031 in
Lead Shielding TVL:	3.0 mm	0.12 in
Critical Organ:	Kidney	
Annual Limit on Intake:	0.3 mCi	
Notes: Shield with Lead For detection of Cd-109 use NaI scintillation survey instruments or gamma counters.		

Ca-45	CALCIUM	^{45}Ca
Half-life:	163 days	
Type of Decay:	Beta –	
Energy of Radiation:	0.257 MeV (100%) maximum	0.076 MeV average
Maximum range in air:	48 cm	19 in
Critical Organ:	Bone	
Annual Limit on Intake:	2.0 mCi	
Notes: Millicurie amounts of Ca045 do not present a significant external exposure hazard because the low energy beta particles barely penetrate the outer dead layer of skin. For detection of Ca-45 use a thin window of G-M survey instruments or liquid scintillation counters.		

C-14	CARBON	^{14}C
Half-life:	5,730 years	
Type of Decay:	Beta –	
Energy of Radiation:	0.156 MeV (100%) maximum	0.049 MeV average
Maximum Beta range in air:	22 cm	8.6 in
Critical Organ:	Whole Body, Fat, Bone	
Annual Limit on Intake:	2.0 mCi	

Notes:

Millicurie amounts of C-14 do not present a significant external exposure hazard because the low energy beta particles barely penetrate the outer dead layer of skin.

Handle potentially volatile compounds in a fume hood.

For detection of C-14 use a thin window C-M survey instruments or liquid scintillation counters.

Cl-36	CHLORINE	^{36}Cl
Half-life:	301,000 years	
Type of Decay:	Beta – (98%) Beta + (.002%)	Electron Capture (2%)
Energy of Radiation:	0.710 MeV (98% beta) max	0.252 MeV average
	0.511 MeV (an x-rays)	
Maximum Beta range in air:	2 m	7 ft
Maximum Beta in water:	2.6 mm	0.1 in
Critical Organ:	Whole Body	
Annual Limit on Intake:	2.0 mCi	

Notes:

Use plexiglass/Lucite shielding (1/4 in).

Cl-36 may present a significant skin dose hazard.

Handle potentially volatile compounds in a fume hood.

For detection of Cl-36 use a thin window G-M survey instruments or liquid scintillation counters.

Cr-51	CHROMIUM	^{51}Cr
Half-life:	27.704 days	
Type of Decay:	Electron Capture	
Energy of Radiation:	0.320 MeV gamma (9.8%)	0.004 MeV e^- (66.9%)
	0.005 MeV x-rays (22.3%)	
Lead Shielding HVL:	1.7 mm	0.07 in
Lead Shielding TVL:	5.6 mm	0.22 in
Unshielded exposure rate from 1 mCi at 1 cm:	180 mR/hr	3 mR/min
Critical Organ:	Lower Large Intestine	
Annual Limit on Intake:	40 mCi	
Notes: Shield with lead. For detection of Cr-51 use G-M survey instruments, liquid scintillation counters, or gamma counters.		

In-111	INDIUM	^{111}In
Half-life:	2.8 days	
Type of Decay:	Electron Capture	
Energy of Radiation:	0.245 MeV gamma (94%)	0.171 MeV average
Lead Shielding HVL:	0.23 mm	0.01 in
Lead Shielding TVL:	2.03 mm	0.08 in
Unshielded exposure rate from 1 mCi at 1 cm:	3210 mR/hr	53.5 mR/min
Critical Organ:	Whole Body	
Annual Limit on Intake:	4.0 mCi	
Notes: Shield with lead For detection of In-111 use NaI scintillation survey instruments or gamma counters.		

I-125	IODINE	^{125}I
Half-life:	60.14 days	
Type of Decay:	Electron Capture – (100%)	
Energy of Radiation:	0.035 MeV gamma	0.027 MeV x-ray
Lead Shielding HVL:	0.02 mm	0.0008 in
Lead Shielding TVL:	0.06 mm	0.0024 in
Unshielded exposure rate from 1 mCi at 1 cm	1400 mR/hr	23.3 mR/min
Critical Organ:	Thyroid	
Annual Limit on Intake:	0.04 mCi	
Notes: Iodine has a very high vapor pressure in solution. Handle potentially compounds in a fume hood (Refer to “Guidelines for Iodinations”).		
For detection of I-125 use NaI scintillation survey instruments or gamma counters.		

I-131	IODINE	^{131}I
Half-life:	8.04 days	
Type of Decay:	Beta – (100%)	
Energy of Radiation:	0.606 MeV B - (89%) 0.334 MeV B - (7.4%) 0.248 MeV B - (2.1%)	0.180 MeV average
	0.364 MeV gamma (81.2%) 0.637 MeV gamma (7.3%) 0.284 MeV gamma (6.1%)	0.080 MeV gamma (2.6%) 0.723 MeV gamma (1.8%) 0.030 MeV x-ray (3.9%)
Maximum Beta range in air:	165 cm	65 in
Lead Shielding HVL:	2.3 mm	0.09 in
Lead Shielding TVL:	8.7 mm	0.34 in
Unshielded exposure rate from 1 mCi at 1 cm:	2160 mR/hr	36 mR/min
Critical Organ:	Thyroid	
Annual Limit on Intake:	0.030 mCi	

Notes:

Shield with lead

Iodine has a very high vapor pressure in solution. Handle potentially volatile compounds in a fume hood. (Refer to “Guidelines for Iodinations”)

For detection of I-131 use G-M survey instruments, NaI scintillation survey instruments, or gamma counters.

P-32	PHOSPHORUS	^{32}P
Half-life:	14.29 days	
Type of Decay:	Beta- (100%)	
Energy of Radiation:	1.710 MeV maximum	0.695 MeV average
Maximum Beta range in air:	6 m	20 ft
Maximum Beta range in water:	8 mm	0.3 in
Unshielded exposure rate from 1 mCi to 1 cm:	26,000 mR/hr	433.3 mR/min
Critical Organ:	Bone	
Annual Limit on Intake:	0.6 mCi	

Notes:

Use plexiglass/Lucite shielding (3/8 inch)

P-32 may present a significant skin and ocular exposure hazard.

Large quantities of P-32 (> 100 mCi) can produce significant secondary radiations which may represent a while body exposure hazard. Shield with plexiglass/Lucite (3/8 inch) in combination with lead (1/16 inch).

For detection of P-32 use G-M survey instruments or liquid scintillation counters.

P-33	PHOSPHORUS	^{33}P
Half-life:	25.4 days	
Type of Decay:	Beta – (100%)	
Energy of Radiation:	0.249 MeV maximum	0.076 MeV average
Maximum Beta range in air:	46 cm	18 in
Critical Organ:	Bone	
Annual Limit on Intake:	6.0 mCi	
Notes: Millicurie amounts of P-33 do not present a significant external exposure hazard because the low energy beta particles barely penetrate the outer dead layer of skin. For detection of P-33 use thin window G-M survey instruments or liquid scintillation counters.		

Rb-86	RUBIDIUM	^{86}Rb
Half-life: 18.66 days		
Type of Decay:	Beta- (99%)	Electron Capture (<1%)
Energy of Radiation:	1.78 MeV maximum	0.667 MeV average
	1.077 MeV gamma (8.8%)	
Maximum Beta range in air:	6.4 mm	21 ft
Maximum Beta range in water:	8 mm	0.3 in
Lead Shielding HVL:	9 mm	0.35 in
Lead Shielding TVL:	32 mm	1.27 in
Unshielded exposure rate from 1 mCi at 1 cm:	500 mR/hr	8.3 mR/min
Critical Organ:	Whole Body, Pancreas, Liver	
Annual Limit on Intake:	0.5 mCi	
Note: Use plexiglass/Lucite shielding (1/2 inch) in combining with lead (>1/4 inch). Rb-86 may present a significant skin and ocular exposure hazard. Rb-86 can produce significant secondary radiations combined with gamma emissions which may represent a whole body exposure hazard. For detection of Rb-86 use G-M survey instruments or liquid scintillation counters.		

Na-22	SODIUM	^{22}Na
Half-life:	2.6 years	
Type of Decay:	Beta + (90.6%)	Electron Capture (9.4%)
Energy of Radiation:	0.546 MeV (B+) maximum	0.216 MeV (B+) average
	1.275 MeV gamma	0.511 MeV and photon (180%)
Maximum Beta range in air:	140 cm	56 in
Lead Shielding HVL:	6.4 mm	0.25 in
Lead Shielding TVL:	19.6 mm	0.77 in
Unshielded exposure rate from 1 mCi at 1 cm:	11,800 mR/hr	197 mR/min
Critical Organ:	Whole Body	
Annual Limit on Intake:	0.4 mCi	

Notes:

Use lead shielding

Na-22 may present a significant skin and ocular exposure hazard

Na-22 can produce significant secondary radiations combined with gamma emissions which may represent a whole body exposure hazard.

For detection of Na-22 use G-M survey instruments, NaI scintillation survey instruments, liquid scintillation counters, or gamma counters.

S-35	SULFUR	^{35}S
Half-life:	87.44 days	
Type of Decay:	Beta – (100%)	
Energy of Radiation:	0.167 MeV maximum	0.048 MeV average
Maximum Beta range in air:	24 cm	9.6 in
Critical Organ:	Whole Body	
Annual Limit on Intake:	6.0 mCi	

Notes:

Millicurie amounts of S-35 do not present a significant external exposure hazard because the low energy beta particles barely penetrate the outer dead layer of skin.
Handle potentially volatile compounds in a fume hood. (Refer to "Guidelines for S-35 Methionine Labeling")

For detection of S-35 use thin window G-M survey instruments or liquid scintillation counters.

H-3	TRITIUM	^{3}H
Half-life:	12.26 years	
Type of Decay:	Beta -	
Energy of Radiation:	0.0186 MeV (100%) maximum	0.005 MeV average
Maximum beta range in air:	4.7 mm	0.19 in
Critical Organ:	Whole Body	
Annual Limit on Intake:	80.0 mCi	

Notes:

Millicurie amounts of H-3 do not present an external exposure hazard because the low energy beta particles cannot penetrate the outer dead layer of skin.

Many tritiated compounds readily pass through the skin. Wear double gloves.

Handle potentially volatile compounds (tritiated water, acetic anhydride, sodium borohydride etc.) in a fume hood.

For detection of H-3 use liquid scintillation counters.