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University of Arizona
Radioactive Materials Protection Reference Guide

Research Laboratory & Safety Services
Revised January 8, 2018

Research Laboratory & Safety Services (RLSS) is the primary coordinating unit responsible for the radiation safety program at the University of Arizona. The Radioactive Materials Protection Reference Guide is maintained at RLSS at 1717 E Speedway Blvd, Suite 1201, Tucson, AZ, and is readily available to anyone via the RLSS website (rlss.arizona.edu).

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I. Introduction

The Radioactive Material Protection Reference Guide serves to describe the Radioactive Materials program at The University of Arizona (UA) and to provide information regarding the safe use of radioactive materials. The responsibilities of the UA Research Laboratory & Safety Services (RLSS), Approval Holders, Approval Safety Coordinators and Radiation Workers are also described.

The program is intended to:

- Provide a basic introduction to radioactive materials and the hazards associated with their use;
- Provide guidance to Approval Holders and radiation workers authorized under their approvals;
- Provide instruction on the acquisition, safe use, transfer, and disposal of radioactive materials;
- Maintain regulatory compliance with applicable state and federal regulations, and
- Inform Approval Holders of the resources available to them through the Research Laboratory & Safety Services (RLSS).

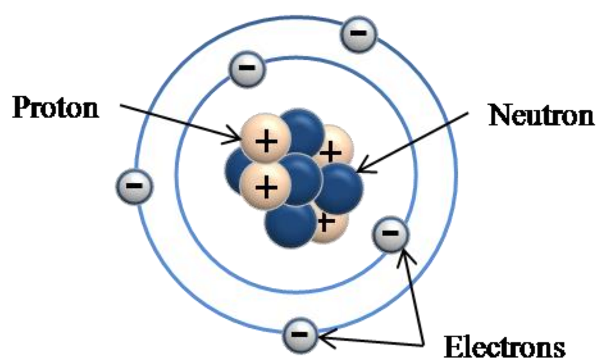
All personnel working with “unsealed” radioactive materials (also described as “wet-chemistry” work) must complete the Radioactive Material Protection Course prior to use of radioactive materials. Course materials and schedules are available on the RLSS website. Approval Holders and Approval Safety Coordinators must also complete an Approval Holders Orientation (provided by RLSS personnel).

II. Physics

A. Atomic Structure

The basic unit of matter is the atom. The basic atomic model, as described by Ernest Rutherford and Niels Bohr in 1913, consists of a positively charged core surrounded by negatively-charged shells (see Figure 1). The central core, called the nucleus, is held together by nuclear forces.

Figure 1: Atomic Structure



Protons (p+) are positively charged particles and neutrons (n) are uncharged particles; both are located in the nucleus of the atom. Electrons (e-) are negatively charged particles that travel in structured orbits, or energy shells, around the nucleus.

An atom is electrically neutral if the total electron charge equals the total proton charge. The term ion is used to define atoms or groups of atoms that have either a positive or negative electrical charge. Isotopes are forms of an element that have the same number of protons, but different numbers of neutrons.

B. Ionizing Radiation

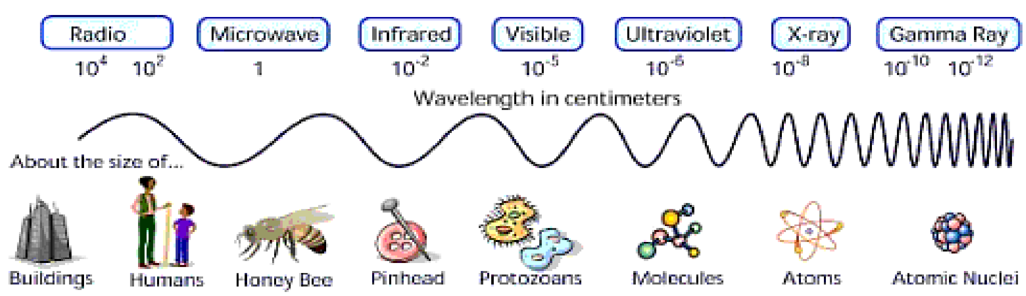
Radiation is the transfer of energy, in the form of particles or waves, through space and matter. Radiation with sufficient energy to create ions by physically removing electrons from neutral atoms is referred to as ionizing radiation. Ionizing radiation includes alpha particles, beta particles, electromagnetic waves, and neutrons. Radiation that lacks the energy to cause ionization is referred to as non-ionizing radiation. Examples of non-ionizing radiation include radio waves, lasers, microwaves, and visible light. The following are four main categories of ionizing radiation.

1. **Alpha Particles**
   The alpha particle is similar to a helium nucleus, comprised of two protons and two neutrons (without surrounding electrons). Alpha particles are heavier and generally more energetic compared to other common types of radiation; however, typical alpha particles travel less than a few inches in air and are stopped by a sheet of paper or the outermost layer of dead cells which protect the skin.

2. **Beta Particles**
   Beta particles are charged particles that come in positive and negative forms. When an unstable atom converts a surplus neutron in the nucleus to a proton, it emits an electron. When an unstable atom converts a surplus proton in the nucleus to a neutron, it emits a positive electron (or positron). Positrons, such as those emitted by ^{18}F, interact with electrons, destroying both and yielding energy (annihilation radiation). That interaction represents a conversion of mass to radiant electromagnetic energy, which can be harmful if not properly controlled. A beta particle has less mass and less charge than an alpha particle, which allows it to travel farther in air, deeper into skin, and through thin shielding and clothing.

3. **Electromagnetic Waves: Gamma Rays (Gammas) and X-Rays**
   Gamma and x-rays differ only in their origin. Gammas originate from an unstable atomic nucleus and x-rays originate from accelerated electrons interacting with matter. Unlike alpha and beta particles, gammas and x-rays penetrate deeply into objects because they do not interact as readily with matter. This is due to their extremely small mass and lack of charge. Both are electromagnetic radiation and differ from radio waves and visible light in that they have a much shorter wavelength, higher frequency and higher energy (see Figure 2).

Figure 2: Comparison of Wavelengths



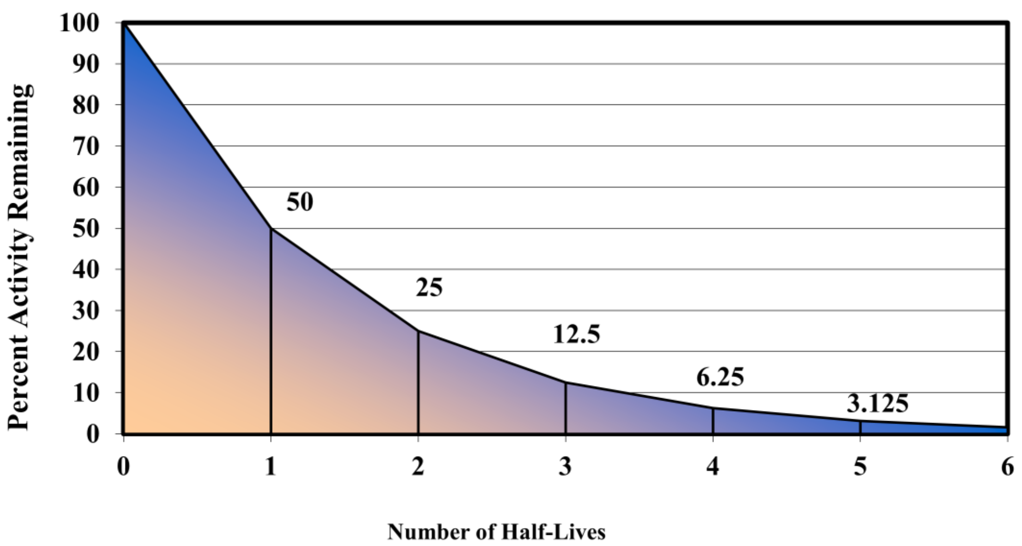
4. **Neutrons**
   Neutrons are nuclear particles that have an exceptional ability to penetrate other materials. Of the types of ionizing radiation discussed here, neutrons are the only ones that can make objects radioactive. This process, called neutron activation, produces many of the radioactive sources that are used in medical, academic, and industrial applications (including oil exploration).
   Because of their exceptional ability to penetrate other materials, neutrons can travel great distances in air and require very thick hydrogen-containing materials (such as paraffin or water) to absorb them. Neutron radiation primarily occurs inside a nuclear reactor, where many feet of water provide effective shielding.

B. Radioactivity and Units of Radiation Measurement

The energy of ionizing radiation is usually measured in electron volts (eV). The electron volt is defined as the kinetic energy gained by an electron when it accelerates through an electric potential difference of one volt.

1. **Radioactive Decay**
   When an unstable atom (or radionuclide) emits energy to become more stable, the radionuclide is said to be "radioactive" and the process of change is called radioactive decay. Radioactive decay is measured in half-life, which is the time required for a radionuclide to lose 50% of its original radioactivity (or activity) by decay. Each radionuclide has a unique half-life ranging from microseconds to billions of years. Radionuclide vendors provide the assay date and assay activity to users so that the original amount of activity on a specified date is known and the remaining activity on any subsequent date can be determined based on the half-life of the specific radionuclide (see Figure 3).

Figure 3: Radioactive Decay/Half-Life Equation



Half-Life Equation

$$A = A_0/2^{t/T_{1/2}}$$

Where,

A = activity (Ci, µCi, kBq, etc.) at time desired
A_0 = original activity (in same activity unit as A)
$T_{1/2}$ = half life of the radionuclide
t = time after the original assay date (in same units as $T_{1/2}$).

2. **Radioactivity Units of Measure**
   Radioactivity is the rate at which radioactive atoms decay. The quantity of a radioactive material is referred to in relation to its activity rather than its mass (e.g. 2 curies of ^{32}P, not 2 grams of ^{32}P).

   The two most common units of activity are the curie and the becquerel. One curie is equal to 3.7 x 10^{10} (37 billion) radioactive disintegrations per second (dps). The becquerel is the System International (SI) unit of activity and one becquerel is equal to one dps. The curie is a very large amount of activity and the becquerel is a very small amount. To make discussion of common amounts of radioactivity more convenient, millicuries (mCi) and microcuries (µCi) or kilobecquerels (kBq) and megabecquerels (MBq) are used (see Table 1).

Table 1: Units of Radioactivity		
Units	**Disintegrations per second**	**System International (SI) units**
1 curie (Ci)	3.7 x 10^{10} (dps)	37 gigabecquerel (GBq)
1 millicurie (mCi)	3.7 x 10^{7} (dps)	37 megabecquerel (MBq)
1 microcuries (μCi)	3.7 x 10^{4} (dps)	37 kilobecquerel (kBq)
1 nanocurie (nCi)	37 (dps)	37 becquerel (Bq)
1 picocurie (pCi)	.037 (dps)	37 millibecquerel (mBq)

1. **Exposure**

Radiation exposure refers to absorption of ionizing radiation or ingestion of a radionuclide. Electromagnetic waves (gammas and x-rays) can produce ionization of air. The unit of measure for ionization of air by electromagnetic waves is the Roentgen (R), where:

1 R = 2.58 x 10^{-4} Coulombs/kg of air

2. **Absorbed Dose**

When predicting biological effects, it is important to determine the energy deposited in human tissue rather than in air or other matter. The total ionizing radiation energy deposited per unit mass of material is the absorbed dose. The rad is the traditional unit of radiation absorbed dose.

1 rad = 100 ergs/gram
1 R = ~0.87 rad (in air); up to 0.96 rad (in tissue)

The SI unit of radiation absorbed dose is the gray (Gy).

1 gray = 1 joule/kg

The relationship between the gray and the rad is:

1 gray = 100 rad

3. **Dose Equivalent**

The dose equivalent is used to measure the biological effects of ionizing radiation on the human body. It is a function of the absorbed dose and the type of radiation absorbed. The weighting factor used according to the type of radiation absorbed is called the quality factor (QF). The rem is the product of the absorbed dose in tissue (the biological dose), calculated by multiplying the rad by a quality factor (see Table 2). This quality factor is used to address the fact that, for the same absorbed dose, different types of ionizing radiation have

Table 2: Quality Factors for Different Radiations	
Radiation	**Quality Factor**
X, gamma, or beta radiation and high-speed electrons	1
Neutrons of unknown energy	10
High-energy protons	10
Alpha particles, multiple-charged particles, fission fragments, and heavy particles of unknown charge	20

differing biological effects in the scope of exposure to low levels of radiation.

Because the quality factor for commonly used ionizing radiation (x-rays, gammas and betas) is one, for radiation safety purposes it may be assumed that:

$$1 \text{ R} = 1 \text{ rad} = 1 \text{ rem}$$

The SI unit for dose equivalent is the sievert (Sv). As it was between the gray and the rad, the relationship between rem and sievert is:

$$1 \text{ Sv} = 100 \text{ rem}$$

II. Biological Effects of Radiation

A. Origins of Biological Damage from Radiation Exposure

Biological effects can be categorized as direct or indirect based on how cellular damage occurs. An indirect effect occurs when free radicals produced by the ionization of water molecules in the body, interact with other molecules or intracellular structures. Most of the time, free radicals interact with molecules that cells can easily survive without.

Radiation that deposits energy directly into intracellular structures (including DNA) results in a direct effect. Changes to DNA can produce cell death, the inability to reproduce, the inability to function, or a change in the function of the cell (mutation), which could lead to cancer. DNA has the ability to repair itself, reverting to its original state or mutating, depending on the type and extent of the damage.

B. Exposure Risks

1. Acute Radiation Dose Exposure

Acute radiation dose is exposure to a large radiation dose over a short time (the period of exposure is considered short when the dose is delivered so quickly that damaged DNA cannot repair itself). At low levels of radiation exposure, the amount of cell death or mutation that results is usually irrelevant and does not impact the function of an entire organ. With an acute radiation dose, large numbers of cells may die and impact the ability of organs to function. Acute radiation dose results in a specific and prompt effect called acute radiation syndrome (or radiation sickness). The dose at which symptoms occur depends on the sensitivity of various cells to radiation. In general, the faster a cell divides and the less specialized it is (e.g. an immature blood cell is less specialized then a mature one), the more sensitive it is to radiation. Immature blood cells are the most radiation-sensitive cells. Effects and outcomes of the three acute radiation syndromes are shown in Table 3. Radiation levels when using unsealed radioactive material at The University of Arizona are too low to result in acute radiation syndrome.

Table 3: Acute Radiation Syndromes			
	Hematopoietic Syndrome (affects blood cell formation)	**Gastrointestinal Syndrome**	**Central Nervous System Syndrome**
Dose (rad)	200-1000	> 1000	> 2000
Time to Death (if fatal)	3-8 weeks	3-10 days	< 3 days
Organ/System Damaged	Bone Marrow	Small Intestine	Brain
Signs & Symptoms	• Decreased number of stem cells in bone marrow • Increased amount of fat in bone marrow • Pancytopenia (reduction in red/white blood cells and platelets) • Anemia (reduction in red blood cells) • Hemorrhage (bleeding) • Infection	• Denudation of villi in small intestine • Neutropenia (reduction in white blood cells) • Infection • Bone marrow depression • Electrolyte imbalance • Watery diarrhea	• Vasculitis (inflammation of the blood vessels) • Edema (water-retention) • Meningitis (inflammation of the brain/spinal cord membranes)
Recovery Time	Dose dependent, 3 weeks to 6 months; some individuals do not survive.	None; fatal	None; fatal

2. Chronic Low Level Radiation Exposure

Chronic low level radiation exposure is exposure to low levels of radiation over long periods of time. The dose effects from chronic low level radiation exposure are delayed effects and include an increased risk of cancer and hereditary effects.

Some other effects, such as skin reddening, cataract formation and temporary sterility in males, occur after receiving a threshold dose (the minimum dose that will produce a detectable degree of any given effect); however, none of these effects have been seen at occupational levels. It is important to realize that the potential risks associated with occupational radiation exposure are similar to, and sometimes less than, risks encountered in daily life (accidental death and the impact of lifestyle choices).

III. Radiation Exposure and Protections

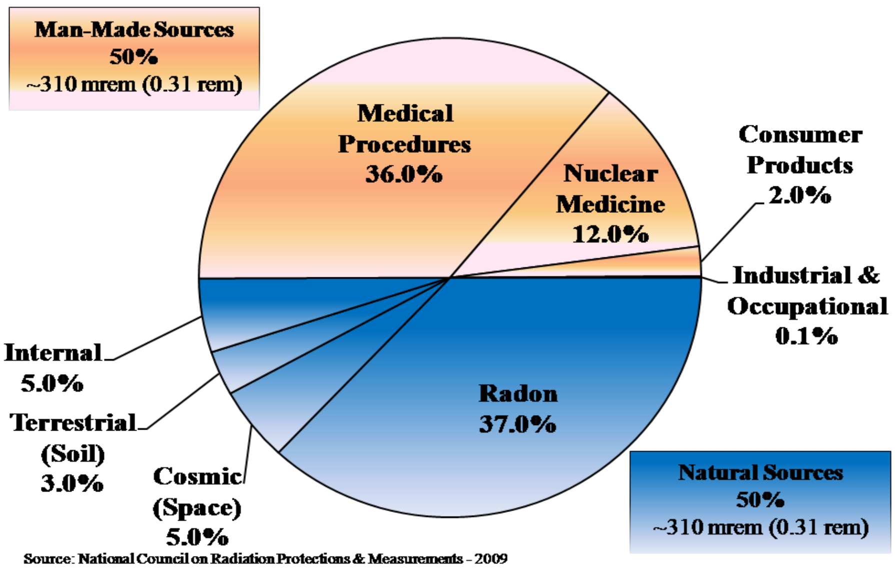
Individuals are exposed to radiation in the normal course of everyday life. Sources of radiation exposure can be classified as natural, man-made, and occupational.

A. Natural Radiation

Natural radiation is the background radiation that is always present in the environment. The main sources of natural radiation are: cosmic radiation which comes from the sun and stars, terrestrial radiation which comes from the earth, and internal radiation which exists within all living things.

B. Man-Made Radiation

Figure 4: Sources of Radiation Exposure in the United States



Man-made ionizing radiation includes medical exposures (such as diagnostic x-rays, fluoroscopy, and other types of imaging, and nuclear medicine diagnostic and treatment procedures), building materials, combustible fuels (including gas and coal), X-ray security systems, smoke detectors, luminous watches, and tobacco.

C. Occupational Dose

Occupational dose is the total dose received by radiation workers in the course of their work. It is important to note that industrial and occupational exposure accounts for only about 0.1% (0.62 mrem) of the average total radiation exposure experienced by an individual annually.

The average radiation dose received by individuals in the U.S. is about 620 mrem/yr (310 mrem/yr from natural sources and about 310 mrem/yr from human-generated sources, including occupational dose). Previously, the total annual dose was estimated at 360 mrem and the change in the current estimate is mainly the result of increased exposure from medical diagnostic and treatment procedures.

Figure 4 illustrates sources of radiation exposure experienced in the U.S and the percentage each represents of an individual's total annual dose. These are only average doses and an individual's dose can vary depending on geographic location, the amount of medical exposures experienced, and various lifestyle choices. For example, smoking (30 cigarettes/day) will expose the lungs to the equivalent of 1.5 rem to the whole body.

D. Occupational Dose Limits

The State of Arizona is a regulatory Agreement State and as such, the U.S. Nuclear Regulatory Commission (NRC) has given the Bureau of Radiation Control (BRC) jurisdiction in regulating work with radioactive materials within the State of Arizona. Limits on occupational doses are based on data regarding known biological effects of ionizing radiation. The International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements publish guidance for setting radiation protection standards. Federal Regulations set regulatory requirements related to radiation exposure and BRC sets regulatory requirements related to radiation protection in the State of Arizona. These limits are set to ensure that the probability of detrimental biological effects from occupational exposure to ionizing radiation is equivalent to what has been observed in other safe industries.

A radiation worker is an individual who has received both general and specific radiation safety training and is authorized to use radioactive materials and/or radiation-producing machines. A non-radiation worker is an individual who is not trained or authorized in the use of radioactive materials and/or radiation-producing machines. The radiation dose received by radiation workers in the course of their work is defined as occupational dose.

Occupational radiation dose limits set by the State of Arizona for different parts of the body and for minors range from 0.5 rem to 50 rem per year (see Table 4). Occupational radiation dose limits are set well below the exposures that cause acute radiation syndrome.

Table 4: Occupational Radiation Dose Limits	
Whole Body	5 rem (5000 mrem)
Lens of Eye	15 rem (15,000 mrem)
Skin of Any Extremity	50 rem (50,000 mrem)
Skin of Whole Body	50 rem (50,000 mrem)
Non-Radiation Worker	0.1 rem (100 mrem)
Minors (personnel under 18 years of age)	10% of adult dose limits
Fetus (total for entire gestation period)	0.5 rem (500 mrem)

1. Pregnant Women: Dose Limits

If a radiation worker is planning to become pregnant or is pregnant, it is recommended that she request information from the Research Laboratory & Safety Services (RLSS) concerning radiation exposure to a fetus. A pregnant woman may choose to declare her pregnancy to RLSS. A declared pregnant woman is a woman who has voluntarily informed RLSS in writing of her pregnancy and the estimated date of conception. It is a regulatory requirement that a declared pregnant woman be provided information about the potential risks of radiation exposure to a fetus.

As part of counseling, RLSS will conduct a review of the work situation and previous exposure history of a declared pregnant woman (or a woman planning to become pregnant) and will provide her with information about her potential for fetal exposure. Based on the work situation review, an additional dosimeter to be worn at the waist and monthly urine bioassay

samples may be required for a declared pregnant woman. The dose limit to an embryo/fetus is 500 mrem over the entire pregnancy. It is also required that every effort be made to avoid substantial variation above a uniform monthly dose rate of 50 mrem/month.

It is a woman's right to “undeclare" her pregnancy at any time. This decision terminates RLSS involvement with her pregnancy even though she may still be pregnant and had previously declared the pregnancy.

2. **Minors: Dose Limits**
Occupational dose limits for minors are 10% of the adult limits. The University of Arizona only allows a minor to become a radiation worker as part of an educational experience, not solely for employment.

E. Protection Against External Radiation Exposure

The concept of ALARA (As Low As Reasonably Achievable) is mandated by both Federal and State of Arizona regulations. The ALARA principle is to maintain radiation dose as far below the occupational limits as is reasonably achievable. This regulatory requirement is based on the following:

- No practice shall be adopted unless its introduction produces a net positive benefit;
- All exposures shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account; and
- The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the regulatory authority.

The ALARA policy is based on the linear, non-threshold (LNT) dose-effect hypothesis. The LNT hypothesis assumes that the known effects of high doses of ionizing radiation may be used to predict the possible effects of long-term, low-dose radiation exposure. According to the LNT hypothesis, there is a relationship between radiation dose and the occurrence of cancer such that any increase in dose, results in an incremental increase in risk. Even though there is disagreement as to whether the LNT hypothesis overestimates or underestimates this risk, Federal and BRC regulations require that The University of Arizona demonstrate that the ALARA principles are being applied.

1. **Keeping Exposures As Low As Reasonably Achievable (ALARA)**
When working with radioactivity, it is essential to keep the radiation exposure to a minimum. The four ALARA principles of time, distance, shielding and minimizing source strength during occupational exposure to radiation are intended to minimize exposure.

a. Time
The dose of radiation a worker receives is directly proportional to the amount of time spent in a radiation field. Reducing the amount of time spent in a radiation field by one-half will reduce the radiation dose received by one-half. Workers should always spend as little time as possible around radioactive materials. The following actions may be used to minimize time of exposure:

- plan work carefully
- read and understand the experiment protocol prior to performing tasks with radiation
- read and understand equipment manuals, if applicable
- rehearse the work procedure with non-radioactive material to identify possible complications
- have all necessary equipment in one place
- ensure all equipment is in good working condition before work begins
- repeat experiments only when absolutely necessary

b. Distance: The Inverse Square Law

Radiation exposure decreases rapidly as the distance between the worker and the radiation source increases. The decrease in exposure from a point source can be calculated by using the inverse square law. This law states that the amount of radiation at a given distance from a point source varies inversely with the square of the distance. Therefore, if the distance to the source is doubled, the exposure decreases by a factor of 4 and if the distance is tripled, the exposure decreases by a factor of 9. The change in percentage of intensity resulting from an increase or decrease in distance from a radiation source is shown in Table 5

Inverse Square Law

$$I_2 = I_1 (D_1/D_2)^2$$

I_1 = original intensity
D_1 = original distance
I_2 = new intensity
D_2 = new distance

Table 5: Effect of Inverse Square Law

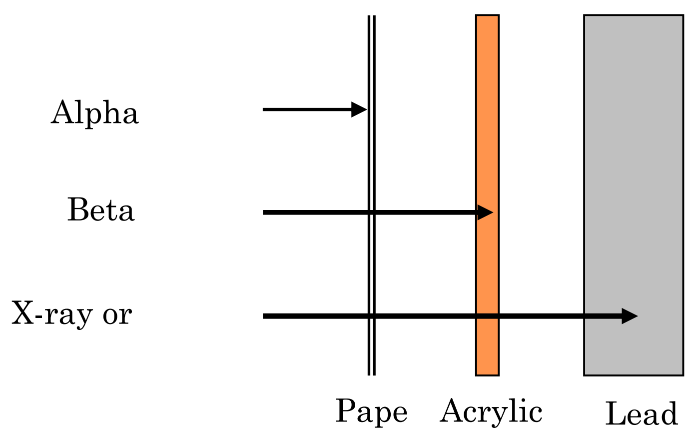
Distance	Intensity
1 foot	100%
2 feet	25%
4 feet	6.25%
10 feet	1%
6 inches	400%

Although the inverse square law does not accurately describe scattered radiation, distance will still dramatically reduce the intensity from this source of radiation. Maintaining a safe distance, therefore, represents one of the simplest and most effective methods for reducing radiation exposure to workers and non-workers.

c. Shielding

Shielding is the use of a material or obstruction to absorb radiation and thus protect personnel or materials from the effects of ionizing radiation. The thickness of the required shielding material is dependent on the energy level of the emitted radiation (higher energy requires thicker shielding). The appropriate type and thickness of shielding material must be used in order to reduce the dose rate of different types of ionizing radiation (see Figure 5). Efficacy of shielding is determined by contamination surveys.

Figure 5: Shielding Materials



Alpha particles can be completely stopped by almost anything (such as a sheet of paper). Beta particles can be shielded by a sheet of acrylic. Use of lead for shielding high-energy beta emitters is discouraged because the resulting bremsstrahlung x-rays can produce significant additional exposures.

Gamma and x-ray radiation is diminished in intensity by any given absorber but not completely stopped. Lead is an appropriate shield for gamma and x-ray radiation, and for photons.

Concrete can also be used as a shield for gamma and x-rays; however, RLSS should be contacted prior to shielding gammas with anything other than lead. Stainless steel or lead- or tin-loaded acrylic viewing windows can also be effective barriers.

Neutrons differ from the ionizing radiation of photons or charged particles in that they are repeatedly bounced and absorbed by light nuclei. Effective shielding material therefore must contain high concentrations of hydrogen, such as is found in water, acrylic, sheets of paraffin, or concrete.

All potentially contaminated containers and instruments, including waste containers, stock solutions and working solutions, should be shielded when appropriate for the particular type of radionuclide.

d. Minimizing Source Strength

The less radioactivity used (given everything else remains the same), the less potential dose that will be received. Advances in modern scientific technique and equipment allow researchers to attain their desired results using smaller amounts of radioactivity than before. In order to minimize exposure and the risk of contamination, unnecessary radioactive material in the laboratory should be removed at the earliest opportunity. Additionally, accumulated waste should be transferred to RLSS on a regular basis for proper disposal.

F. Measurement of External Exposure to Radiation

Various types of radiation dosimeters (including badge, extremity or ring, and supplemental/secondary dosimeters) are used to measure an individual's external exposure to radiation; badge dosimeters cannot measure the absorbed dose from alpha or low energy beta particles because of their low energy. The need for personal dosimeters is dependent on the frequency, quantity and specific nuclides used. Individuals who are likely to receive at least 10% of the occupational dose limit will be assigned a dosimeter. Badge, extremity and supplemental/secondary dosimeters are issued free of charge by RLSS. Whether or not a dosimeter is assigned, or whether bioassays are required (for monitoring internal exposure), is determined by a health physicist.

1. Badge Dosimeters

Badge dosimeters (see Figure 6) are the primary type of whole body personal dosimeter provided by RLSS. These dosimeters are typically collected by RLSS on a bimonthly basis and sent to their manufacturers to be analyzed. The dosimeter should not be exposed to temperatures above 150^{o} F, as this may affect the exposure measurements that are obtained.

Figure 6: Badge Dosimeter

(showing front of unit and front/back of holder)

2. **Extremity (Ring) Dosimeters**
   Extremity (ring) dosimeters are used to measure exposure to the hands when whole body exposure and hand exposure could differ significantly (see Figure 7). The “chip side” of the finger ring must be aimed towards the palm and must be worn on the designated hand.

Figure 7: Extremity (Ring) Dosimeter

3. **Supplemental/Secondary Dosimeters**
   Pocket ion chambers and electronic personal dosimeters are two types of supplemental/secondary dosimeters. An ion chamber is an instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume. A pocket ion chamber is an ion chamber the size of a fountain pen and is used to detect gamma or neutron ionizing radiation exposure. It provides the user with an immediate measurement of exposure.

   An electronic personal dosimeter is an electronic unit capable of measuring gamma, beta and x-radiation exposure. It provides the user with immediate feedback as to the current rate of exposure as well as exposure over a specified period of time
   (see Figure 8).

Figure 8: Electronic Personal Dosimeter

   Pocket ion chambers and electronic personal dosimeters are only issued on an as needed basis and proper use requires additional training and documentation. The number of available units is limited due to high cost.

G. Protection Against Internal Exposure to Radiation

Radioactive material can be damaging to the body if absorbed, inhaled, injected or ingested (swallowed).

- Absorption
  Skin should be protected against the absorption of radioactive material. Laboratory coats, gloves, eye protection and other types of coverings should be used to reduce the risk of absorption. It is also recommended that open wounds be covered.

- Inhalation
  If using potentially airborne radioactive materials such as gases, vapors, volatile materials or powders, the use of fume hoods may be required.
- Injection
  Injections can occur with any sharp objects, including broken glass.
- Ingestion
  Laboratory rules prohibiting eating (including chewing gum), drinking, smoking, applying cosmetics, or mouth pipetting in approved radiation work areas are intended to reduce the risk of internal exposure by ingestion.

Surveys and appropriate containment/decontamination procedures also minimize risk of internal exposures.

H. Measurement of Internal Exposure to Radiation

The amount of radioactive material incorporated into the body may be measured through a bioassay. A bioassay is a test to determine the kind, quantity, or concentration (and sometimes the location) of radioactive material in the human body, either by direct measurement or by evaluation of bodily fluids or tissue. Bioassay services currently available from RLSS include urine sampling and thyroid gland scanning.

1. **Urine Bioassay**
   Urine bioassays are used by RLSS to determine the presence of radioactive material in the body. Urine bioassays may be used to monitor exposures in declared pregnant women, workers using volatile chemical forms of radioactive materials, workers using a large amount of radioactive material, radiation workers under 18 years of age, and individuals who may have been accidently exposed. Urine bioassays can be used to measure the internal levels of most radioactive isotopes.

2. **Thyroid Bioassay**
   Thyroid bioassay is performed for laboratory or clinical radiation workers using radioactive iodine. This bioassay is available upon request, takes approximately five minutes, and involves a non-invasive scanning procedure.

IV. Laboratory Practices

All individuals working with radioactive material (RAM) should be aware of the location of the necessary documents, records, and guidelines that pertain to RAM use approvals. A visiting RLSS or state inspector may ask to view this information at any time.

A. Education and Training

Individuals may not work with RAM until they have received appropriate training. In conjunction with RLSS, this is a two-part process that includes on-the-job training and completion of the Radioactive Material Protection Course. Course schedules and registration information are located on the RLSS website. Approval Holders should maintain the course completion certificates for all radiation workers under their approval. RLSS training must be completed and submitted to RLSS before an individual begins working in a new laboratory or under an additional approval.

B. Approval to Use Radioactive Materials

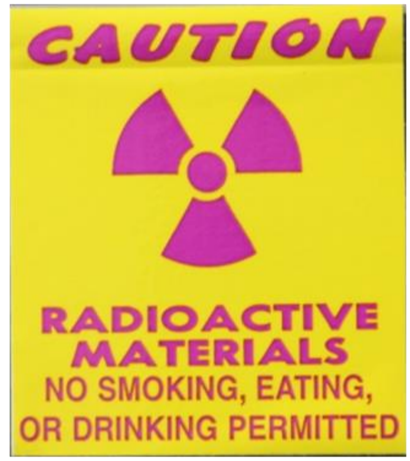
An ‘Approval to Use Radioactive Materials' is granted to an individual after the Radiation Safety Committee reviews and approves a New Radioactive Material Approval Application. The radionuclides that will be used, their activity and chemical forms, the protocols, and the rooms where the material will be used and stored must be specified in the application. To change approved protocols, add radionuclides, or raise activity limits, an Approval Holder is required to submit an Application to Amend RAM Approval for review and approval by the Radiation Safety Committee.

In addition to RLSS approval, proposed experiments may require additional regulatory approvals from the Institutional Animal Care Use Committee (IACUC), the Institutional Review Board (IRB) at the Human Subjects Protection Program office, or the Institutional Biosafety Committee (IBC).

C. Posting and Labeling of Areas Containing Radioactive Materials

Once a room is approved for RAM use or storage, RLSS will post the required signs. No work involving RAM may be initiated until the signs have been posted.

Figure 9: Sample Sign



1. **Room and Area Entrances**
   "Caution Radioactive Materials, No Eating, Drinking, or Smoking" (see Figure 9)

2. **Notice to Employees (Form ARRA-6)**
   This document summarizes the rights and responsibilities of State radiation workers, and radiation exposure protections required by the BRC.

3. **Radiation Emergency Procedures Form**
   This form provides brief information for emergency situations, phone numbers for Approval Holders and Approval Safety Coordinators approved to use the posted area, and RLSS and UAPD phone numbers.

4. **Adjacent RAM Work Area Notice**
   This notice is only posted in areas that have been designated for use of RAM in an open bay laboratory. The Approval Holder is responsible for training non-radiation workers in these areas.

5. **Labeling of Radioactive Materials, Containers and Ancillary Equipment**
   In addition to the signage provided by RLSS, it is the responsibility of all radiation workers under the approval to provide appropriate labeling for radioactive materials, tools, equipment, and areas within laboratories where radioactive materials are located or used.

   - "Caution Radioactive Material" (CRM) signs must be posted on each RAM storage location, fume hoods, refrigerators/freezers, and cabinets, etc., within a laboratory.
   - RAM containers, radioactive equipment (may include centrifuges and incubators, etc.), radioactive tools (may include pens, pipettes, beakers, etc.), and radioactive waste containers must also be clearly labeled.
   - Bench tops where RAM is used and floor spaces where waste is stored must be delineated with CRM warning tape.

D. Dosimetry Use

The measurements obtained by a dosimeter are a legal record of a person's individual radiation exposure and RLSS maintains these records for personnel using RLSS-issued dosimeters. Personal dosimeters issued by RLSS may not be shared or exposed to any source of radiation outside of the specific work assignment for which they were issued. If a dosimeter is issued, it must be worn whenever working with radioactivity in the work assignment.

A lost or damaged badge should be reported immediately to RLSS. A worker may not perform any work with radioactive materials until a new badge has been obtained. RLSS will immediately replace any damaged or lost dosimeter; however, a replacement fee may be charged to the department for lost dosimeters; the department may pass the charge on to the responsible individual. Current information pertaining to the use of dosimeters, monitoring and documentation of exposure is located on the RLSS website.

E. Receipt, Inventory and Security of Radioactive Materials

All incoming and outgoing RAM must be routed through RLSS.

1. Receipt

All incoming packages of RAM are surveyed for contamination by RLSS, assigned an RMR# (radioactive material receipt number), and entered into the inventory database. RAM is then delivered to the requesting laboratory along with a packing slip and 'Radioactive Materials Inventory and Survey Log'.

2. Inventory

Once the RAM is delivered, the Approval Holder is required to maintain records of the RAM inventory on the Radioactive Materials Inventory and Survey Log. Each use, the volume dispensed, and method of disposal for each shipment of RAM must be documented. If releases to the environment (e.g., via fume hood or sink) are greater than 40 nCi (0.04 µCi) total nuclides per month, a disposal log must also be maintained and the releases must be reported to RLSS each month.

Transfer of any RAM, whether internally to another Approval Holder, or externally to another institution must be done via RLSS. Prior to any internal transfers of RAM, RLSS must be contacted to assure that the isotope, chemical form, and amount of RAM are permitted under the recipient's current Approval. At the same time, the radionuclide, amount and assay date of the RAM that is to be transferred must be reported to RLSS for inventory purposes. RLSS will provide a record of the transaction to both Approval Holders.

For transfer of RAM to an external site, RLSS must be notified at least 24 hours before scheduling the transfer so that the appropriate paperwork may be completed in advance. A copy of the NRC/State license must be obtained from the intended recipient and may be faxed directly from the recipient company or institution to RLSS. Transfer of RAM to other countries may sometimes take months to arrange.

3. Security

It is the responsibility of the Approval Holder to ensure that RAM is secure from unauthorized use or theft. All individuals who are authorized to enter a radiation use area have the responsibility to adhere to RAM security measures. These individuals may include radiation workers, non-radiation workers or others who are authorized to enter the radiation use laboratory (including University support personnel).

Unless determined otherwise by RLSS or the Radiation Safety Committee, RAM must be secured by:

- keeping it under constant "line of sight" surveillance by a radiation worker (authorized under that approval), or
- by locking the RAM use or storage area/laboratory, or
- by placing RAM in locked storage (such as a cabinet or refrigerator with a lock) within an approved RAM use or storage area/laboratory.

Under the following conditions, RAM must be secured in a locked storage container (such as a cabinet or refrigerator with a lock) whenever not under constant "line of site" surveillance by a radiation worker.

- Approvals for 100 mCi or more of ^{3}H, or
- Approvals for a total of 50 mCi or more of other radionuclides, or
- Approvals for use of RAM in open bay laboratories.

When the total of all RAM in a designated RAM use area (including waste) is less than 40 µCi, RLSS or the Radiation Safety Committee may reduce the security and control requirements, however posting and labeling requirements still apply.

The physical securing of RAM must be combined with preventing unauthorized entry into the laboratory. Visitors must be questioned as to their purpose for being in a radiation laboratory. Visitors and outside contractors shall be under constant supervision by a radiation worker when in radiation use areas unless all RAM has been secured and all RAM work areas are found to be free of contamination via a comprehensive, documented survey. UA Facilities Management personnel and custodial staff have been trained to work safely around RAM, so supervision is not required.

Any known or suspected loss or theft of RAM must be reported immediately to RLSS.

F. Contamination Surveys

Approval Holders are responsible for ensuring that required surveys are performed as part of a continuous radiation-monitoring program for their laboratories and facilities. Surveys may be wipe surveys or instrument surveys, as is appropriate for the particular radionuclide and activity approval (see RLSS website for information about performing surveys). If counts in excess of 50 counts per minute (cpm) above background are found during any survey, the area must be decontaminated, and initial and follow-up survey results recorded.

1. After Use Surveys

Anyone using RAM is expected to survey work areas (hoods, sinks, bench tops, floors, etc.) after each use and at any time there is reason to suspect contamination, a spill, or an incident involving the radionuclide in use. A permanent record of these use area surveys must be kept for three years even if no contamination is found.

2. Monthly Surveys

A complete survey of all approved laboratories must be performed on a monthly basis. These surveys are for all approved radionuclides and must include areas such as waste storage areas, desks, refrigerator handles, and phones, etc. For open bay laboratories, the scope of monthly contamination surveys must include both radiation use and non-radiation use areas of the laboratory (non-radiation use areas include adjacent RAM work area floors, equipment and bench tops, open bay entrance thresholds and doorknobs, high traffic floor areas, and equipment directly adjacent to RAM use areas). If no RAM is in possession during an entire month (including no RAM waste), no survey needs to be performed for that month.

3. Follow-up Surveys

If decontamination of an area is required for any reason, a new survey of the contamination area must be performed to document the return to background levels.

G. Instruments

Geiger-Mueller (GM) type detectors, Low-Energy Gamma Scintillation Counters, Liquid Scintillation Counters and Dose Rate Meters (ionization chambers) are commonly used to perform surveys of RAM use areas. The type of detector to be used is dependent on the type of radionuclides being used or that are approved for use (see Table 6). Recommended scale for surveys is counts per minute (cpm).

1. **GM Detectors**
   GM detectors are used with end-window or pancake probes (see Figure 12 and Figure 11). Some GM detectors include a scale in milliroentgen per hour (mR/hr), but survey results must be expressed in counts per minute (cpm).

2. **Low Energy Gamma (LEG) Scintillation Counters**
   LEG scintillation counters are more sensitive than and may have a higher background rate than GM detectors and are therefore useful in measuring low energy photons. These detectors are very fragile and must be handled carefully.

3. **Liquid Scintillation Counters**
   Liquid Scintillation Counters are used to measure activity found in wipe survey samples placed in liquid scintillation cocktail (LSC). This reading is compared to a background reading (determined by placing an unused wipe in LSC) in order to identify any areas requiring decontamination.

4. **Dose Rate Meters (Ionization Chambers)**
   Dose Rate Meters are used for measurement of absorbed dose rate (see Figure 10). They are used primarily by RLSS to determine dose.

Table 6: Required Survey Instruments for Approved Radionuclides

Emitter	**Detector**		
	GM (Pancake or End Window Probe)	**Low Energy Gamma Scintillator**	**Liquid Scintillation Counter**
Low Energy Betas (e.g., ^{14}C, ^{35}S, ^{7}H)			X
High Energy Betas (e.g., ^{32}P)	X		X
Low Energy Gammas (e.g., ^{51}Cr, ^{125}I)		X	X

Figure 11: Dose Rate Meter

Figure 10: Detector Probes

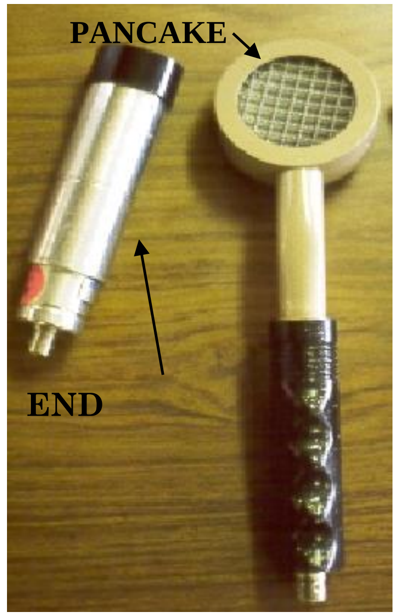


Figure 12: Sample GM Detector

H. Radioactive Waste

Radioactive waste must be segregated in a manner that allows the University to dispose of it in the safest and most efficient manner possible. Prior to submitting a waste collection request, waste must be properly packaged and labeled, identifying the content of containers by attaching separate, completed Radioactive Waste Summary Forms to each. Waste collections are requested online via the RLSS website.

1. Classification of Radioactive Waste

Waste must be classified and separated according to its physical and radiological properties. Materials that are potentially contaminated must be disposed of as radioactive waste. The following are seven basic physical classifications:

- Animal Bodies: Animal remains consisting of the carcass and any attached tissue or organs.
- Biological Waste: Harvested tissue or organs, bodily fluids or excretions, and other materials (e.g., bedding, items that came in contact with a radioactive animal).
- Dry Waste: Solids (e.g., gloves, pipette tips, absorbent materials); metals, such as lead RAM storage containers or mercury isotopes, must be separated from other dry waste.
- Aqueous Liquids: Liquids containing chemicals listed as “Aqueous” on the RLSS website.
- Mixed (Organic) Liquids: Liquids containing chemicals listed as “Organic (Mixed)” on the RLSS website.
  [Aqueous and mixed (organic) liquids must not be placed in the same container. Mixtures containing organic solvents, halogenated liquids and/or metal containing liquids should be separated from other chemicals due to the cost of disposal.]
- Scintillation Vials: LSC vials (glass or plastic) for disposal.
- Scintillation Bulk: Liquid scintillation fluid in the original container or in pails.

The following are three basic radiological classifications:

- Deregulated Waste: Scintillation or animal body waste containing ^{3}H and/or ^{14}C with concentrations less than 0.05 µCi per ml or per gram.
- Short-lived (<120 days) waste
- Long-lived (>120 days) waste
  (Short-lived and long-lived waste must not to be mixed together.)

2. Radioactive Waste Storage

Radioactive waste should be collected in a secure, low traffic area of the laboratory, separated from other types of waste (e.g., biohazardous or non-radioactive chemical waste). The floor area where radioactive waste containers are stored must be delineated with radioactive labeling tape and all waste must be properly labeled. Two Waste Classification Labels (provided by RLSS), 180º apart, must clearly identify the radionuclide(s) present. Prior to requesting RLSS collection, all infectious agents in the waste must be deactivated in accordance with the experimental protocol. Gamma and high-energy beta waste must be shielded if count rates exceed double the background count rate.

3. Packaging of Radioactive Waste

Waste must be properly packaged to ensure safe handling and should be placed in the smallest container that will accommodate it. Dry and liquid waste must not be mixed. The document, Rules for Packaging Radioactive Waste, is available on the RLSS website.

- Dry waste - Place in yellow plastic bags, cardboard boxes lined with yellow plastic bags, or sealed plastic pails. Liquid waste may not be processed as dry waste by use of absorbents.
- Sharps - Place in puncture resistant containers, preferably sealed pails; an item is considered sharp if it can puncture a plastic bag.
- Liquids - Place all types in polyethylene jugs or sealed plastic pails; aqueous liquids can also be disposed of in cubitainers.
- Biological waste - Place in polyethylene jugs or sealed plastic pails; animal bedding, blood-stained diapers and bench covers may be disposed of in doubled yellow bags.
- Animal bodies - Place in doubled yellow bags or sealed pails.
- Scintillation vials - Place upright in the original tray in the original cardboard box lined with a yellow bag, or in sealed plastic pails.
- Bulk scintillation cocktail - Place in original container, polyethylene jugs or sealed plastic pails.

4. Radioactive Waste Summary Form

A completed Radioactive Waste Summary Form must be attached to each container. The approval number, who prepared the form, contact phone number, type of waste, physical description, chemical constituents, and RMR number must be on the completed form.

Figure 13: Sample Waste Form

Research
Research Laboratory & Safety Services

PO Box 245101
Tucson, AZ 85724-5101
Voice: (520) 626-6850
FAX: (520) 626-2583
rlss.arizona.edu

Radioactive Waste Summary Form
MARK ALL BOXES [ ] THAT APPLY

Section 1
Approval # ____________ Prepared By: ___________________________ Phone: ______________

Section 2 [ ] Biological Waste [ ] Deactivated Biohazard (all biohazards must be deactivated)
Describe Below:
[ ] Animal Carcasses
[ ] Animal Byproducts
[ ] Medical Waste
[ ] Other ________________

Deactivated pathogen / infectious agent(s)

Describe deactivation method

Section 3 [ ] Dry Waste [ ] Sharp
Describe sharp contents below:

Section 4 [ ] Scintillation Cocktail
List cocktail brand name(s) below:
[ ] Scintillation Vials
[ ] Bulk Cocktail

Section 5 [ ] Liquid Waste
List all Chemicals / Compounds in Liquid Waste
Include all Common and Special Compounds found online at http://rlss.arizona.edu
Ensure that metal containing, halogenated and organic compounds are included

Compounds / Chemicals	Approx Vol. %	Compounds / Chemicals	Approx Vol. %

Section 6
List all radioactive material by RMR#

Nuclide	Assay Date	RMR #	Activity in mCi	Nuclide	Assay Date	RMR #	Activity in mCi

ATTACH TO WASTE ITEM THIS SIDE UP

For RLSS USE ONLY – Not for Distribution

04/28/2015

V. Emergency Procedures

Radiation workers should familiarize themselves with the Emergency Procedures document posted in each laboratory approved for work with RAM. The Approval Safety Coordinator is the designated person, other than the Approval Holder, who can provide information about source use in the laboratory in case of an emergency.

A. Radioactive Material Spills

A spill is defined as any accidental or unplanned release of RAM such as, contamination in any unrestricted area, removable contamination in any restricted area, or any personnel contamination. Spills are classified as minor or major, depending on how widespread or controlled the contamination is and how much danger is present for those working in the area. RLSS is available to assist in decontamination efforts.

The initial steps taken in the event of a spill are represented by the acronym, SWIM.

Stop the spill (turn containers upright and prevent spread of spilled material)
Warn other personnel
Isolate the area
Minimize exposure to radiation and contamination

1. **Minor Spills**

A minor spill of RAM is defined as an unintentional release of radioactivity that is confined to a small area, and which presents no significant health hazard to any workers in the area. Normal operations may not be resumed in the spill area until decontamination has been completed and checked. In the case of a minor spill, the following actions should be taken by radiation workers as soon as possible:

- Confine the spill immediately (wear disposable gloves).
- Notify Approval Safety Coordinator or Approval Holder.
- Notify people nearby, and keep personnel not essential to the decontamination effort out of the spill area.
- Do not let personnel who may be contaminated leave the general area until they have been checked.
- Decontaminate the area. Dispose of all potentially contaminated materials in yellow bags or other properly marked radioactive waste containers.
- Perform and document contamination surveys.

If assistance is needed, call RLSS (if after business hours or if no answer at the RLSS telephone number, call University Police). Once notified, RLSS will support laboratory workers' decontamination efforts and provide necessary dosimetry services.

2. **Major Spills**

A major spill of RAM is defined as an unintentional release of radioactivity that has potentially spread over a large area and/or may pose a significant health hazard to workers in the area. The Approval Safety Coordinator, Approval Holder and RLSS must be notified as soon as possible. Once notified, RLSS personnel will arrive on site, conduct decontamination efforts, and provide necessary dosimetry services. Normal operations may not be resumed in the spill area until decontamination has been completed and checked. In the case of a major spill, the following actions should be taken by laboratory personnel as soon as possible:

- Confine the spill as much as possible without risking serious self-contamination. Methods of confinement may include covering liquid spills with absorbent paper or carefully dampening powders to prevent dispersion. If possible, containers should be turned upright.
- Notify the Approval Safety Coordinator and RLSS as soon as possible. If after business hours or if no answer at the RLSS telephone number, call University Police.
- Decontamination must not be attempted without assistance from RLSS personnel.
- Notify people nearby who are not needed for spill response to leave the immediate area, but to remain nearby as a group so that they can be surveyed for contamination.
- Identify the location and extent (area) of spill. If it can be done safely, mark off spill area.
- Turn off all devices that may spread contamination. If possible, leave hood fan on and sash at proper height.
- Leave the area quickly and lock the door. Remove gloves and shoes, if contaminated, before leaving the area.
- Remain nearby to ensure that no one enters the area and to provide information when help arrives.
- Remove contaminated clothing and go to nearest available 'clean area' and follow the advice of RLSS personnel.
- Skin that may be contaminated should be washed thoroughly with water.

B. The Process of Decontamination

Each laboratory should have supplies available for performing radioactive decontamination. These supplies include gloves, RAM tape for marking off contaminated areas, a mild soap or decontamination agent (such as Contrad® or de-con®), paper towels, and yellow bags or appropriate containers for waste.

1. **Personnel Decontamination**
   - Any cuts or open wounds that may have been contaminated should be thoroughly flushed under running water.
   - Contaminated clothing should be removed and affected skin washed with soap and water.
     - Skin should be washed repeatedly until monitoring indicates a return to background levels, taking care not to abrade or break the skin.
     - If washing with soap and water proves to be ineffective, a series of increasingly aggressive steps can be taken until background level is attained, but these procedures should only be done under RLSS guidance.
2. **Area Decontamination**
   - Wear protective clothing while performing decontamination.
   - Start decontamination process with less contaminated areas and move towards more contaminated areas, in order to minimize spread.
   - When using decontamination liquid, use the minimum volume possible.
     - Increased contact time usually increases the effectiveness of the decontamination liquid.
   - Always dispose of cleaning materials in the radioactive waste.

C. Fire Emergencies Involving Radioactive Materials

- In case of fire, call ‘911’ from a University telephone, notify dispatcher that radiation is involved, pull the nearest fire alarm, and vacate the building.
- Call RLSS (if after business hours or if no answer at the RLSS telephone number, call University Police).

D. Loss or Theft of Radioactive Materials

Suspected loss or theft of RAM must be reported immediately to the Approval Safety Coordinator and/or Approval Holder, and RLSS. If after business hours or if no answer at the RLSS telephone number, call University Police.

VI. Responsibilities by Role

The responsibility for maintaining radiation doses to workers and the public under the ALARA principles is shared by RLSS, the Approval Holder, the Approval Safety Coordinator, and each radiation worker.

A. Approval Holder Responsibilities

Approval Holders are the individuals ultimately responsible for the safe use of RAM under their control and listed on their approval. Approval Holder Orientation is provided by RLSS at the time of approval, during audits, and/or at a minimum of every three years. Approval Holders have the responsibility to:

- Comply with the rules and regulations administered by the University Radiation Safety Committee or the Medical Radiation Safety Committee, RLSS, and the BRC;

- Properly train radiation workers to handle, secure, and dispose of RAM under their Approval in accordance with the Radiation Training Policy, Basic Laboratory Procedures for Unsealed Radioactive Materials and Rules for Packaging Radioactive Waste;
- Provide in-house training;
- Ensure that RLSS is notified of new proposed radiation workers;
- Provide adequate supervision of authorized radiation workers;
- Maintain a written inventory of RAM, reconciled with the RLSS inventory report on a monthly basis;
- Ensure that contamination surveys are performed and documented, as required;
- Report any environmental releases that exceed 40 nCi total nuclides/month to RLSS;
- Respond to information requests by RLSS in a timely manner;
- Notify RLSS immediately if an exposure has occurred or is suspected;
- Maintain all required postings and labeling for RAM use areas, for RAM, and for tools associated with RAM;
- Provide and ensure proper use of personal protective equipment, if required;
- Notify RLSS prior to relocation or transfer of RAM (to internal or external sites);
- Notify RLSS if the Approval Holder will be absent from the institution for an extended time that will reduce the effective oversight of laboratory operations. If an extended absence is planned, an agreement must be reached with an appropriate substitute to oversee the use of RAM while the Approval Holder is away.

B. Radiation Safety Coordinator Responsibilities

Some Approval Holders may not have the time or resources to personally monitor the day-to-day operation of a laboratory. Therefore, Approval Holders may appoint a Radiation Safety Coordinator to operate under their Approval, but the ultimate responsibility for use of the RAM remains with the Approval Holder. The Radiation Safety Coordinator, in addition to attending the Radioactive Materials Protection Course will receive an Approval Holder Orientation from RLSS personnel (initially, during audits, or at a minimum of every three years). At the direction of the Approval Holder, the Radiation Safety Coordinator may be assigned extra responsibilities such as those in the above list.

C. Radiation Worker Responsibilities

Radiation Workers have the responsibility to:

- Complete the Radioactive Materials Protection Course and any other required training prior to beginning work;
- Notify RLSS if transferring to a new Approval Holder's group or laboratory;
- Comply with the requirements for the safe use and security of RAM, and for proper disposal of waste;
- Perform and document required contamination surveys;
- Report all accidents and exposures (known or suspected) to the Approval Safety Coordinator and/or Approval Holder, and to RLSS.

D. Research Laboratory & Safety Services (RLSS) Responsibilities

RLSS has responsibility to:

- Provide training (e.g., Radioactive Material Protection Course, Approval Holder's Orientation);
- Receive shipments of RAM and inspect for contamination prior to delivery to requesting laboratory;

- Maintain a current inventory of RAM;
- Calibrate survey instruments;
- Provide signs for entrances to RAM use areas and for labeling of waste containers;
- Provide personnel dosimeters and area monitors, if necessary;
- Maintain exposure records for Radiation Workers;
- Perform audits and laboratory inspections (at least annually);
- Provide assistance in contamination surveys and decontamination procedures, as needed.

VII. Purchasing Radioactive Materials

A. Consolidated Purchasing Program (CPP)

The CPP provides an option for RAM Approval Holders to order RAM centrally in order to reduce cost. The program is available through RLSS and provides universal access to commonly ordered RAM at the lowest available price with shared shipping costs and expedited processing of orders. CPP orders are placed via the RLSS website and order deadlines and delivery schedules are also available at that site. It is recommended that a printed copy of the confirmation receipt be retained when order is placed.

B. Purchase Order

For purchase of RAM directly from vendors or other institutions, a Purchase Requisition should be generated. Departmental Purchasing Cards may not be used to purchase RAM; this violates University mandated Policy Restrictions that apply to the Purchasing Card.

The purchase requisition must contain all of the following items (applies to new and replacement shipments).

- Approval Holder name
- Approval Number
- Radionuclide
- Activity being ordered in mCi or μCi
- Chemical form and Catalog number
- Protocol Number
- Object Code 5240

All incoming shipments of RAM must be delivered to:

Attn: Research Laboratory & Safety Services
Medical Receiving Dock
1501 N Campbell Ave
Tucson, AZ 85724
OR
Research Laboratory & Safety Services
University of Arizona
College of Medicine, Phoenix Campus
425 N 5th Street
Phoenix, AZ 85004