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Scope and applicability

Procedures and information in this manual apply to all personnel working at or visiting ASU who dispose of, procure or utilize radioactive material.

Radioactive material includes all sealed and unsealed sources. Sealed sources of radioactive material contained within machinery, such as liquid scintillation counters, gas chromatographs and static eliminators, are within the scope of this manual.

Radiation-producing equipment not containing radioactive material, such as X-ray equipment, electron microscopes, lasers and radio-frequency generators, is not covered. Procedures and information regarding the safe use of lasers or radiation-producing equipment, including X-ray equipment, electron microscopes and radio-frequency generators, may be found in the ASU Laser Manual and ASU Radiation Producing Equipment training, respectively.

ASU procures and uses radioactive material under a license issued by the Arizona Department of Health Services Bureau of Radiation Control. The license requires that ASU personnel use Bureau of Radiation Control-approved procedures to acquire, control and dispose of all radioactive material. Personnel must follow these procedures to ensure compliance with the Bureau of Radiation Control license granted to ASU.

Section one: Radiation safety organization at ASU

1.1 Radiation AZDHS Bureau of Radiation Control

ASU procures and uses radioactive material under ADHS BRC License #7-37. The license requires that ASU personnel use Bureau of Radiation Control-approved procedures to acquire, control and dispose of all radioactive material. These procedures include those applicable to all institutions using radioactive material as contained in the State of Arizona Radiation Regulatory Agency Rules and Regulations and other conditions specified in the license granted to the university. These procedures are designed to protect individuals in the university community from unnecessary exposure to ionizing radiation.

ASU is subject to inspection by the Bureau of Radiation Control. Suppose the Bureau of Radiation Control finds that ASU is not compliant with license conditions. In that case, it may issue fines or, in the case of serious infractions, suspend or revoke the license.

The Bureau of Radiation Control's rules and regulations and license issued to ASU and supporting documentation is on file with Environmental Health and Safety for review by ASU personnel.

1.2 Radiation safety officer

The radiation safety officer is responsible for implementing the radiation safety program as directed by the ASU Radiation Safety Committee. The radiation safety officer is an Environmental Health and Safety department member.

The radiation safety officer and trained and approved Environmental Health and Safety staff do the following:

- Assist in the management of incidents involving radioactive material.
- Collect and process radioactive waste.
- Conduct radiation safety training.
- Manage the radiation dosimetry program.
- Perform radiation safety surveys.

- Receive and in-process radioactive material.

The radiation safety officer is available as a consultant on the safety aspects of radioactive material use and for information on experimental design. They have the authority to suspend or prevent the use of radioactive material by individuals and seize radioactive material when, in their opinion, work is being conducted in a hazardous manner or in a way that constitutes a violation of the Bureau of Radiation Control rules and regulations or conditions of Bureau of Radiation Control License issued to ASU. The Radiation Safety Committee reviews these actions of the RSO.

1.3 ASU sub-licensees

All disposal, possession and use of radioactive material at ASU must be conducted under the auspices of a sub-license issued by the RSC or RSO. Sub-licenses are given to professionals at ASU who have applied for and received permission to use radioactive material in a specified research or education program.

Sub-licensees are responsible for all work conducted under their sub-license. Their responsibilities include:

- Ensuring that the conditions of their sub-license and approved procedures of ASU and the Bureau of Radiation Control are followed when disposing of, procuring, and using radioactive material.
- Guaranteeing that their sub-license is current concerning quantities of radioactive material used, procedures being used and location of use.
- Training and supervising users handling radioactive materials under their sub-license.

Procedures for sub-license application are contained in section two of this manual.

1.4 Approved users

Approved users are personnel of the radiation safety officer designated in writing as individuals who may use radioactive material without direct supervision. Authorized users must use radioactive material under a sub-license or sub-licenses specified in writing by the ASU RSC.

The sub-licensee maintains overall responsibility for approved users' use of radioactive material.

1.5 Visitors

Sub-licensees are responsible for seeing that visitors to spaces containing radioactive material are not exposed to radiation from the material. Visitors who plan to participate in work involving the use of radioactive material must contact RSO for appropriate briefings and dosimetry devices.

1.6 Minors

Minors or persons under 18 are not allowed in ASU spaces containing radioactive material unless permission is obtained from the RSO. Children of university employees are not permitted in these spaces.

Personnel under the age of 18 who desire to work with radioactive material must receive written permission to do so from the RSO.

Section two: Obtaining permission to use radioactive materials

2.1 Sub-licensees for the use of radioactive material

All radioactive material at ASU is procured and used following provisions of a sub-license issued by the RSC or RSO. In general, sub-licenses will be given only to full-time faculty or staff of ASU. Temporary or adjunct faculty members must use radioactive material under the direction of an ASU RSC-approved user under a sub-license held by a full-time faculty or staff member. Temporary and adjunct faculty are individuals as defined in the ASU Faculty Handbook and include post-doctoral personnel and instructors.

2.1.1 Application for new sub-licensees

Applications for new sub-licenses are made by submitting ASU Radioactive Materials Sub-License Application Forms to the RSO. Forms and instructions for their completion are available on request by contacting Environmental Health and Safety. The radiation safety officer has the authority to temporarily approve sub-licensees for using and storing radioactive material equal to or less than quantities listed in table 2-1 below. The ASU RSC reviews these sub-licenses at the meeting following approval by the RSO. The ASU RSC may modify or revoke temporary sub-licenses issued by the RSO when, in their opinion, the training and experience of the users are inadequate, or the procedures are unsafe. For nuclides not listed in table 2-1, the limits are ten times the exempt activities listed in the Arizona Administrative Code 12-1, Article 3 Schedule B.

2.1.2 Sub-license conditions

Radioactive material sub-licenses must be specific concerning the following:

Nuclide	Activity — uCi
^{195}Au	100
^{14}C	1,000
^{45}Ca	100
^{109}Cd	100
^{14}Ce	1,000
^{57}Co	1,000
^{60}Co	10
^{51}Cr	10,000
^{59}Fe	100
^{3}H	10,000
^{203}Hg	100
^{125}I	10
^{111}In	1,000
^{22}Na	100
^{24}Na	100
^{32}P	100
^{86}Rb	100
^{103}R	100
^{35}S	1,000
^{46}Sc	100
^{113}Sn	100
^{85}Sr	100
^{89}Sr	10

Table 2-1: Maximum activities of radionuclides which may be given temporary approval for use by the RSO include the following:

- Experimental procedures for each nuclide.
- Nuclides to be used, including chemical or physical form, the maximum quantity of each nuclide stored in the laboratory, the maximum quantity of each nuclide stored in a single container and the maximum quantity of each nuclide used in each experimental procedure.
- One or more locations in which radioactive material is stored and used.

The ASU RSC may impose other conditions for using radioactive material when the sub-license is issued or anytime after that.

2.1.3 Amendments of sub-licensees

Sub-licenses must be amended before procedure changes, or other conditions are listed in paragraph 2.1.2. Amendments are requested as follows:

- Currently licensed nuclides are made by way of a memorandum to the RSO. These changes include:
  - Activity limits for currently licensed nuclides.
  - Chemical or physical form of currently licensed nuclides.
  - Location of use of currently licensed nuclides.
  - Procedures for the use of currently licensed nuclides.
- Radionuclides used under an existing sub-license are made through a memorandum to the radiation safety officer. Use of the ASU Radioactive Materials Sub-License Application Form is optional. Information about presently licensed material is not required.

The RSO has the authority to give temporary approval to amendments for nuclides to be used and stored in quantities equal to or less than those listed in table 2-1. The ASU RSC reviews these amendments at the meeting following approval by the RSO. The ASU RSC may modify or revoke amendments approved by the RSO when the committee feels the training and experience of users is inadequate, or the new procedures are unsafe.

2.1.4 Responsibilities of the sub-license holders

In addition to the responsibilities listed in paragraph 1.4, sub-licensees must:

- Comply with the regulations of the Bureau of Radiation Control and with the conditions of their radioactive materials sub-license.
- Ensure that users of radioactive material are adequately trained and supervised.
- Notify the RSO before all extended absences from campus.
- Request amendments before implementing new procedures or other changes that would violate the conditions of the sub-license.

2.1.5 Responsibilities of approved users

Unsupervised use of radioactive materials by approved users must be conducted as directed by the sub-licensee under whose sub-license work is being conducted. Authorized users may not use radioactive material unsupervised or supervise the use of radioactive material under sub-licenses other than those specified by the ASU RSC. Approved users must know and observe the conditions of the sub-license under which they are working and know the procedures for using radioactive material as stated in these regulations and the regulations of ARRA.

2.2 Training required of personnel handling radioactive material

All personnel working with radioactive material at ASU must receive periodic training on radiation safety and ASU procedures for using radioactive material.

2.2.1 Radiation safety training

All personnel, regardless of previous training and experience, must attend radiation safety training under the direction of the RSO before beginning work with radioactive material. Please email EHS or call 480-965-6140 to register for the training. The training will last two to three hours and include a test that must be passed with an 80 percent. Information will consist of the following:

- Applicable provisions of ARRA rules and regulations and the rules and regulations established by ASU as specified in this manual.
- Health effects of exposure to low doses of ionizing radiation.
- Precautions and procedures to minimize exposure to ionizing radiation.
- Response in the event of spills and emergencies.
- Responsibilities of personnel using radioactive material.
- Rights of workers to have access to radiation exposure records.
- Types and amounts of radiation or radioactive materials to which workers could be exposed while working at ASU.

2.2.2 Annual radiation safety training

All personnel working with radioactive material must attend the annual refresher training presented under the direction of the radiation safety officer. All sub-licensees are notified before the time and place for these training sessions. Topics covered during these classes include those covered at the briefing and others selected by the radiation safety officer. These classes are approximately one hour in length.

2.2.3 Training and experience required for sub-licensees

Personnel granted sub-licenses will be required, as a minimum, to have 16 hours of formal radiation safety training. Personnel using large quantities of radioactive material or using unusual or hazardous procedures may require additional training or experience in the processes involved. Training obtained at locations other than ASU may meet these training requirements. The ASU RSC may waive some or all of the training requirements on presenting evidence of appropriate experience in using radioactive material. However, personnel must document at least six months of routine experience with the procedures involved.

Section three: Personnel dosimetry and regulatory limits

3.1: Monitoring radiation doses from external sources

3.1.1 Thermoluminescent dosimeter and TLD badges

TLD badges are used at ASU to monitor personnel for exposure of the body to penetrating ionizing radiation, such as gamma and X-rays and skin exposure to less penetrating radiation, such as beta particles. For most individuals, results of the TLD badge readings are also used as estimates for the exposure of the eye's lens. TLD badges must be worn by personnel working with most sources of ionizing radiation. TLD badges may not be required for individuals handling the following radioactive materials:

- ^{3}H, ^{14}C and ^{35}S.
- Material contained in gas chromatographs or other equipment as a sealed source.
- Micro-curie quantities of material in check sources and radio-immuno assay kits.

TLD badges must be worn on the body's trunk at or above the waist. Dosimetry devices must not be taken home or left in laboratory areas where they may be exposed to radiation from radioactive material. The TLD badge is sensitive to heat and humidity. False positive readings may result when badges are left in hot cars, near hot windows or other heat sources.

3.1.2 Extremity dosimetry

At ASU, ring dosimetry devices are used to monitor for radiation exposure to the hands. They are issued to personnel handling millicurie quantities of ^{32}P or other complex beta emitters and to personnel handling significant gamma-emitting sources. Ring badges must be worn under gloves with the sensitive portion of the ring toward the source.

3.1.3 Dosimeter exchange

TLD badges and rings will be hand delivered by EHS during the last few days of the quarter. EHS will collect the old badges after the start of the new wear period. For any old TLDs and rings missed during this pickup, please contact EHS. Campus mail must not be used. This policy has been established to avoid exposure of TLDs to radiation, heat and humidity sources during transit.

3.1.4 Lost, damaged or unreturned badges

EHS provides radiation dosimetry free of charge; however, a $20 fee will be charged to the department for each dosimeter individuals fail to return. The department has the option to recover the fee from the delinquent party.

3.2 Monitoring for exposure from internal radioactive materials

3.2.1 Thyroid bioassay

All personnel handling more than 100 uCi of ^{125}I or ^{131}I during a calendar month must have a thyroid scan within 6–72 hours of use. Thyroid scans are obtained at the EHS office on a walk-in basis.

3.2.2 Urine bioassay and whole-body counts

Individuals handling more than 10 mCi of ^{3}H in any given month must submit a urine sample for analysis to RSO within 6–72 hours of use. Personnel handling significant unsealed sources of radioactive material other than ^{3}H may be required to submit urine samples or submit to a whole-body count.

EHS staff will notify individuals requiring bioassays as needed.

3.3 Regulatory dose limits

3.3.1 Limits for radiation workers

ARRA has imposed limits on the dose of ionizing radiation that may be received by individuals working with sources of ionizing radiation. These limits are shown in table 3-1:

Annual limit, which is the more limiting of: a. Total effective dose equivalent. b. Sum of the deep dose equivalent and committed dose equivalent to any organ or tissue other than the eye's lens.	• 5 rem or 0.05 Sv. • 50 rem or 0.5 Sy.
Eye dose equivalent	• 15 rem or 0.15 Sy.
A shallow dose equivalent to the skin or each of the extremities.	• 50 rem or 0.5 Sy.

Table 3-1: Regulatory dose limits.

3.3.2 Limits to the embryo or fetus of declared pregnant workers

Due to concerns about prenatal radiation exposure, as written in Appendix B, ARRA regulations provide separate limits for the fetus of declared pregnant workers. The limit is 0.5 rem dose equivalent to the fetus during pregnancy.

This limit only applies to workers who have formally declared pregnancy in writing. Declaration of pregnancy should be sent to the RSO and include the estimated date of conception.

Individuals concerned about radiation and pregnancy should feel free to speak to RSO.

3.3.3 Limits for members of the public

The regulatory limit for members of the public is 0.1 rem total effective dose equivalent per year. This limit applies to all individuals who are not trained to work with sources of ionizing radiation. At ASU, this includes most students, faculty and staff.

3.4: As low as reasonably achievable

Given uncertainties concerning the health effects of exposure to low doses of radiation, it is prudent to keep doses to personnel ALARA. Each user of radioactive material at ASU is responsible for incorporating shielding and protective devices and taking any other steps required to keep doses ALARA.

3.4.1 Investigational levels

To maintain doses ALARA, investigational dose levels have been established at ASU. These dose levels are shown in table 3-2. The limits are evaluated quarterly.

Personnel exposures equal to or greater than Investigational Level 1 will be reviewed by the RSO, who will report the results to the ASU RSC at their next regularly scheduled meeting. The ASU RSC may require corrective actions by the RSO or sub-licensee.

Personnel exposures equal to or exceeding Investigational Level 2 will be investigated promptly by the RSO, who will take immediate action if warranted. A report of the investigation steps taken, and a copy of the individual's radiation dosimetry history will be presented to the ASU RSC at their regularly scheduled meeting following the completion of the investigation. The ASU RSC may impose restrictions on the user and additional conditions on the sub-license under which the exposed individual was working, as warranted.

Investigational limits exceeding those listed in table 3-2 may be established by the ASU RSC for a worker or group of workers when the higher investigational levels are consistent with good ALARA practice for the work being conducted by the individual or group.

Limit	**Level — rem and quarter**	
	Level one	**Level two**
Total effective dose equivalent	0.065	0.200
Eye dose equivalent	0.180	0.600
Shallow dose equivalent to the skin or each of the extremities	0.625	2.000

Table 3-2: Investigational dose levels.

3.5 Reports to workers on radiation dosimetry

EHS keeps careful records of radiation dosimetry and bioassay results for personnel in the ASU dosimetry program. These records are available for review by these personnel.

3.5.1 Annual dosimetry report

During the spring of each year, a report on dosimetry results for the previous calendar year is sent to each individual who is issued a dosimeter at ASU. A summary of individual dosimetry results is also sent to the sub-licensee responsible for supervising the work requiring dosimetry.

3.5.2 Notification of results exceeding investigation limits

Personnel will be notified quickly of results exceeding the investigation levels in tables 3-4. Personnel is not notified quarterly of routine dosimetry results, which do not exceed the investigation levels.

3.6 Radiation dosimetry units

The following paragraphs explain the dosimetry units used in this section.

3.6.1 Absorbed dose

The amount of energy absorbed by irradiated tissue is essential in assessing radiation risk and damage. The absorbed dose is defined as the energy absorbed per unit mass of tissue. The traditional unit for absorbed dose is the rad.

- 1 rad = 100 erg per gram.

The rad is being replaced by a new unit based on the International System of Units. The new unit is the gray.

- 1 gray = 1 joule per kg.

Spending a little time with the units will reveal that 1 gray = 100 rad.

The SI units have not found widespread use in radiation protection in this country. However, it is the system of units that is used internationally and will eventually replace the older units here.

3.6.3 Dose equivalent

Alpha, beta, gamma, X-radiation, and neutrons differ in tissue damage produced for a given absorbed dose. Special units of dose equivalent are used to adjust the absorbed dose for this difference. The traditional unit of dose equivalent is the rem.

- 1 rem = 1 rad x Q.

Q is called the quality factor and is assigned to radiation based on the relative risk for a given dose. Currently a quality factor of “1” is used for photons, electrons and positrons. A quality factor of 2.3 to 10 is used for neutrons, depending on their energy and a quality factor of 20 is used for alpha particles. The SI unit for dose equivalent is the sievert.

- 1 sievert = 1 gray x Q.

Radiation type	Q
X and gamma rays	1
Beta particles	1
Alpha particles	20
Neutrons	2.3 to 10

Table 3-3: Radiation quality factors.

3.6.3 Exposure

The energy absorbed by irradiated tissue is rarely measured directly. Most radiation detection instrumentation used in radiation protection measures the number of ion pairs produced in a volume of gas. The traditional unit used to measure ionization in the air is the roentgen:

- 1 roentgen = 2.58 x 10-4 coulombs per kg air.

The roentgen is defined only for X-rays and gamma rays. It is not used for beta, alpha or neutron radiation.

Exposure of 1 roentgen of radiation results in an absorbed dose to the tissue of 0.97 rad. For radiation protection and dosimetry, it is usually assumed that the roentgen, rad and rem are numerically equivalent for gamma rays and X-rays.

3.6.4 Effective dose equivalent

The body's various organs and tissues differ in their radiation sensitivity. For instance, the bone marrow and other body's blood-forming tissues are much more sensitive to radiation than the body's skin. To quantify the risk from radiation exposure when the body is not irradiated uniformly — different doses are delivered to other organs or tissues— a unit called the effective dose equivalent has been developed. The effective dose equivalent is given the symbol H and is defined as:

- $H = \Sigma D_i W_i$.

Di is the dose equivalent received by the i-th tissue or organ, and Wi is a weighting factor assigned to the i-th tissue or organ depending on its sensitivity to radiation. Weighting factors currently in use are listed in the accompanying table. The units of the effective dose equivalent are the rem and the sievert, depending on which is used for the individual tissue or organ dose equivalent.

Tissue	Weighting factor
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30
Whole body	1.00
The 0.30 for the remainder results from 0.06 for each of the five remaining organs, excluding the skin and eye lens, which received the highest doses.	

Table 3-4: Effective dose equivalent weighting factors.

3.6.5: Committed effective dose equivalent

When radioactive materials are inhaled, ingested or otherwise internalized, they may be retained in some tissues for an extended period. Sometimes, a fraction of the material may remain in the body for years. The committed dose equivalent is the dose equivalent that tissues or organs will receive from an intake of radioactive material during the 50 years following the intake. The committed effective dose equivalent is the effective dose equivalent received from an intake of radioactive material by an individual during the 50 years following the intake.

3.6.6 Deep dose equivalent

The deep dose equivalent is the dose equivalent at a tissue depth of one centimeter.

3.6.7 Shallow dose equivalent

The shallow dose equivalent is the dose equivalent at a tissue depth of 0.0007 centimeters averaged over one square centimeter.

3.6.8 Eye dose equivalent

The eye dose equivalent is the dose equivalent to the eye's lens.

3.6.9 Total effective dose equivalent

The total effective dose equivalent is the sum of the committed effective dose equivalent for all intakes of radioactive material and the deep dose equal to the whole body resulting from exposure to external radiation sources.

Section four: Laboratory procedures for the use of radioactive materials

4.1 Posting of laboratories and space for the use of radioactive material

All work with radioactive material must be conducted in spaces approved by the radiation safety officer under the direction of the ASU Radiation Safety Committee. The radiation safety officer posts entries to these spaces with signs containing the yellow and magenta radiation warning symbol. The warnings on the signs will vary according to the following conditions:

- Spaces approved for radionuclide use but not containing significant radiation fields are labeled with signs containing the following words:
    - Caution radioactive material.
    - Danger radioactive material.
- Spaces in which the radiation field could lead to personnel receiving a whole-body dose of five millirems in an hour or 100 millirems in any five consecutive days are posted with signs containing the following words:
    - Caution radiation area.
- Spaces in which the radiation fields could lead to personnel receiving a whole-body dose of 100 millirems in any hour are posted with signs containing the following words:
    - Caution high radiation area.
    - Danger high radiation area.

Additional signs and warnings may be posted for contaminated spaces or other purposes. All instructions on or with signs containing radiation warnings should be strictly obeyed.

Radioactive material may be taken into unposted spaces for educational purposes only under provisions of a sub-license granted by the radiation safety officer or the ASU Radiation Safety Committee. This radioactive material must be attended to by the sub-licensee or a user for whom the sub-licensee is responsible.

4.2 Labeling and storage of radionuclides

4.2.1 Labeling

Regulations require that containers with radioactive material over the limits specified in table 4-1 be labeled with the nuclide, activity, date and name of the user. Limits for nuclides not specified are contained in Arizona Administrative Code 12-1, Article 4 Appendix C. Containers with lesser amounts of radioactive material should be labeled when practical. Racks or boxes containing several samples with small amounts of radioactive material may be labeled instead of a label on each vial.

Nuclide	Activity — uCi
^{14}C	1,000
^{45}Ca	100
^{57}Co	100
^{60}Co	1
^{51}Cr	1,000
^{59}Fe	10
^{3}H	1,000
^{125}I	1
^{22}Na	10
^{32}P	10
^{35}S	100

Table 4-1: Labeling.

4.2.2 Storage

All radioactive material must be stored so that radiation fields are less than those specified for a radiation area in sub-section 4.1 unless specific approval is obtained from the radiation safety officer. Radioactive sources must be secured against unauthorized removal at all times. This means that one of the following conditions must be met:

- Material is attended to by a responsible person authorized to work with radioactive material.
- Material is contained in a locked container.
- The room in which the material is stored is locked.

4.3 Contamination control

4.3.1 General rules for contamination control

- Accidental contamination can be avoided by working carefully and regularly monitoring the work area.
- All radioactive waste must be placed in marked containers, which EHS has approved.
- Assigned dosimetry devices must be worn as required.
- Disposable gloves and lab coats must be worn when handling unsealed sources of radioactive materials. Lab coats must not be taken from the lab to lunch rooms.
- Do not eat, drink, smoke, chew gum or apply cosmetics in spaces where unsealed sources of radioactive material are used.
- Do not store food, drink or personal items with radioactive material.

- In case of a spill or personal contamination, know how to react.
- Label containers of radioactive material indicating nuclide, total activity and date.
- Solutions should never be pipetted by mouth.
- The area within the laboratory where unsealed sources of radioactive material are used must be covered with absorbent material surrounded with yellow tape or tape with the standard radiation caution symbol. Work should be conducted in a tray lined with absorbent paper and in a chemical or radionuclide fume hood if possible.
- The smallest quantity of radioactivity compatible should be used with the objective of the experiment.

4.3.2 User surveys for surface contamination

After procedures using unsealed sources of radioactive material are complete or at the end of each day during which radioactive materials are used, the work areas must be surveyed for surface contamination. The extent of the survey depends on the type of procedures being conducted and the amount of radioactive material.

Using activities equal to or less than those in paragraph 4.2.1 requires a check for contamination in the immediate work area and on the hands and feet of those handling the material.

Complicated procedures and those involving quantities of radioactive material over those listed in paragraph 4.2.1 require more extensive surveys, including checks on surfaces such as the floor, table tops, phones, doorknobs, feet, hands and other areas where there is a potential for the spread of radioactive material.

Surveys must be documented. The individual conducting the survey must initial or sign a document indicating that the survey was conducted and whether the contamination was or was not found. The documentation may be through the source utilization logs or other logs provided by the user.

4.3.3 Survey procedures

Surveys for some nuclides may be made using a laboratory survey instrument. Surveys for other nuclides, such as H-3, require wiping surfaces with filter papers. Removable activity on the filter papers can be counted using liquid scintillation. Specific procedures for some nuclides in use at ASU are:

- ^{14}C, ^{35}S, ^{45}Ca or ^{125}I: G.M. counters with narrow windows of about 1.2 to 2 mg/cm2 may be used for detecting areas of gross contamination. However, the efficiency of thin window G.M. detectors for these nuclides is such that contamination over allowable limits may not be detected. A final check must be conducted using filter paper wipes as outlined for ^{3}H.
- ^{3}H: Wipe surfaces with filter paper and count by liquid scintillation for five minutes. The surfaces should be decontaminated if the count rate is more than 15 CPM above the background.
- Laboratory survey techniques for other nuclides may be obtained from the radiation safety officer.
- ^{32}P and other hard beta emitters: These nuclides are adequately detected with laboratory survey meters. The probe should be placed within a couple of millimeters of the surface and moved very slowly. Surfaces with more than 50 CPM readings above the background should be decontaminated.

4.3.4 Contaminated surfaces and equipment

Instruments and glassware, which are repeatedly used with radioactive materials, may be stored in their contaminated condition if they are bagged, marked with the radiation warning symbol and placed in a closed container such as a drawer or cupboard, which also shows the radiation warning symbol. Interior surfaces of some equipment, such as centrifuges, may contain low-level contamination if the equipment is appropriately marked and closed so that contaminated surfaces are not exposed to the

room. Measurable contamination must not be allowed to remain on equipment and laboratory surfaces other than those listed above. The radiation safety officer must approve exceptions to this policy.

4.3.5 Laboratory survey by radiation protection personnel

Personnel from EHS enter laboratories and spaces designated for using radioactive materials periodically to conduct surveys. Personnel conducting surveys make measurements of surface contamination and radiation levels. They also examine laboratory records and observe laboratory conditions for compliance of the sub-licensee and users of radioactive material with ARRA and ASU rules and regulations for using radioactive material. Most spaces in which radioactive material is used are surveyed by EHS personnel monthly. Laboratories using radioactive material on an infrequent basis will be surveyed by EHS personnel annually.

4.3.6 Sealed source leak checks

Sealed sources containing more than 100 uCi of beta or photon-emitting material or more than 10 uCi of alpha-emitting material are tested for leakage every six months by EHS personnel. Sub-licensees are contacted for access to sources as needed. Should leakage over 0.005 uCi be discovered on these sources, the radiation safety officer removes them from use and repairs or disposes of them.

4.4 Protection from external exposure

4.4.1 ^{3}H, ^{14}C and ^{35}S

External exposure to radiation emitted by these low-energy beta emitters is not a problem unless they are present as contamination on the skin's surface. Beta particles from these nuclides travel less than 25 cm or 10 inches in the air and less than 0.3 mm or 0.1 inches in tissue. Most radiation is absorbed by containers, solutions, air, clothing and the dead layer of skin. The beta particle from tritium does not have sufficient energy to penetrate the dead layer of cells protecting the skin.

4.4.2 Limiting the time of exposure

The external dose received is a function of the time spent working in the proximity of radioactive materials. Plan procedures in advance and examine how to do the job, which will speed the procedure and limit the time that exposure to radiation is necessary. Equipment which eliminates the need for direct handling of radioactive material is desirable.

Practice procedures using non-radioactive materials. These dry runs will increase the worker's ability to conduct experiments quickly and carefully.

4.4.3 Maximizing distance from sources

For sources of radiation that are small in physical size, the intensity of the radiation field is inversely proportional to the square of the distance from the source. The importance of the so-called "inverse square law" lies in the quadratic relationship between exposure rate and distance. By doubling the distance between a worker and the source, the exposure rate is decreased by a factor of four. Distance should be maximized by using remote handling instruments, such as tongs, for handling vials of radioactive material and by staying away from the source whenever possible.

4.4.4 Shielding beta particles

Shielding pure beta emitters is simplified by the lack of more penetrating radiations. Beta particles have a finite range of shielding materials beyond which they cannot penetrate. The best shielding for ^{32}P is plastic, Lucite, glass and aluminum.

The use of lead or other high atomic number shielding materials may create penetrating bremsstrahlung radiations. Lucite and plexiglass are easily worked materials for constructing beta shields. One-fourth inch of these plastics will protect users working with millicurie quantities of ^{32}P. Beta shields in various configurations can be obtained commercially. Information on sources of these shield materials is available in the EHS office.

Nuclide	Radiations	Range of "b" particles in the air	[1]Dose rate to the skin from 1 uCi/cm^2 skin contamination (rad/hr)	[2]Annual limit on intake (mCi)
^{3}H	18.6 keV b	0.5 cm	0.0	80
^{14}C	156.5 keV b	0.2 m	1.2	2
^{32}P	1.7 MeV b	6.2 m	8.9	0.6
^{35}S	166.7 keV b	0.24 m	1.3	2
^{36}Cl	709.3 keV b	1.9 m	7.2	0.2
^{45}Ca	256.7 keV b	0.46 m	3.3	0.8
^{59}Fe	465.6 keV b 1.1 MeV g 1.3 MeV g	1.1m - -	4.7 - -	0.3 - -
^{125}I	35 keV electrons 30 keV X-rays 35 keV g	1.5 cm - -	$2x10^{-3}$ - -	0.04 - -

[1] Dose rate estimated for basal skin cells.

[2] Amount of ingested or inhaled radioactive material resulting in a five-rem effective dose equivalent. The number listed is the smallest of the inhalation and ingestion ALI.

Table 4-2: Characteristics of nuclides in common use at ASU.

4.4.5 Shielding of gamma and X-rays

Lead or other high atomic number materials are most efficient for shielding gamma and X-rays. The thickness depends on the photon's energy and the source's activity. One-quarter inch of lead will reduce radiation from ^{125}I by a factor of 100. Over two inches of lead is required for a comparable reduction in radiation from Co-60.

Radioactive materials should be stored in shielding such that the dose rate to people in the laboratory is less than 2 mrem/hr. Lead-shielded storage pigs, lead sheets and lead bricks are commercially available for shielding photons. The radiation safety officer should be consulted when designing or evaluating shielding.

4.5 Internal contamination

All radioactive materials will expose body tissues if inhaled, ingested, injected or otherwise introduced into the body, provided in table 4.2. Prevention of internalization of material is through contamination control, including clean work habits and frequent user surveys.

4.6 Skin contamination

When nuclides are present on the skin's surface, relatively large doses may be delivered quickly, provided in table 4.2. Wear gloves at all times during the use of radioactive material. If contaminated, the skin should be washed immediately. In all cases of skin contamination, the radiation safety officer should be notified immediately.

Section five: Source procurement and accountability

5.1 Ordering radioactive material

The Advantage system is used for purchasing radioactive material at ASU. Personnel from the Purchasing department obtain approval for these purchases online or through written permission on hard copies of the requisition. To process orders for radioactive material:

1. Complete information using Advantage — use object code 7320 10 for radioactive material.
2. In the appropriate space, specify that delivery is to be made to the radiation safety officer or trained and approved staff.
3. Describe the items in terms of the nuclide, the chemical or physical form of the nuclide and the activity in uCi or mCi.

5.1.1 Procurement other than by purchase order

Radioactive material in any quantity must not be obtained for use at ASU without the approval of the radiation safety officer. Before arrangements are made with organizations or individuals to get radioactive material, the organization or person from which the material is obtained must have certification from the radiation safety officer that ASU is licensed to receive it. The RSO is responsible for seeing that DOT and NRC regulations concerning transport and receipt of the source are adhered to.

5.1.2 Receipt of radioactive material

All radioactive material shipped to ASU facilities is sent to the RSO. Upon receipt of radioactive material, the RSO or trained and approved EHS staff will survey the material for radiation levels and surface contamination.

The responsible user is notified of its arrival. Radioactive material is delivered to users by the RSO or EHS staff.

5.2 Transfer of radioactive material to other users at ASU

The RSO must approve a transfer of radioactive material between sub-licensees at ASU before transferring the material.

5.3 Radioactive material accountability

5.3.1 Source control number

Each vial or source containing radioactive material is given a Source Control Number when it arrives at ASU. The Source Control Number assists users in tracking down information on orders and keeping track of material in each laboratory.

A Source Utilization Log is issued to users for each vial of consumable radioactive material when it is delivered by the RSO or EHS personnel. The user updates the log when radioactive material is disposed of as waste. The log remains in possession of the user until all of the radioactive material in the vial has been disposed of, at which time the log is returned to RSO or EHS staff. These records must be maintained in the laboratory to assist in keeping track of radioactive material in work areas and be available for review by the RSO and EHS personnel, state inspectors, and auditors. All entries should be as accurate as possible but may be conservative estimates when exact quantities are unknown. Logs may be corrected for radioactive decay at the discretion of the sub-licensee.

5.3.2 Quarterly radioactive source inventory

At the end of each calendar quarter, a computer printout with a list of radionuclide sources in possession of the user is sent to each sub-licensee. Sources are identified by source number, radionuclide and chemical or physical form.

The sub-licensee must conduct a physical check for all radioactive material. Sources in possession of the user which are not listed on the printout or those listed which are not in the user's possession must be brought to the attention of the RSO. The activity of sources on hand should be checked and corrected if there are changes due to disposal or decay.

Section six: Shipment and transport of radioactive material

6.1 Shipment and transport of radioactive material to off-campus locations

Radioactive material must not be removed from ASU property without prior notification and approval from the RSO. The RSO will direct the packaging and transportation of the material. This restriction includes the movement of:

- Radioactive material between the main campus and other ASU-owned facilities, such as the Animal Care Facility or the Community Services Building.
- Sealed check sources or sources contained in equipment, such as liquid scintillation counters and chromatographs.
- Small amounts of radioactivity in samples or culture media.

6.2 Transportation of radioactive material between buildings on an ASU campus

Radioactive material moved between buildings of the Tempe campus must be packaged to prevent spillage of liquid or powdered material. The material should be in closed containers with tight-fitting lids. These containers should be labeled appropriately, as stated in paragraph 4.2.1. Enough absorbent material should surround glass containers to prevent material loss during breakage. The material should be shielded such that the exposure rate one meter from the package surface is less than 10 mR/hr. Packages with exposure rates over 10 mR/hr at the package surface should be transported using a cart and not carried by hand.

6.3 Transportation of radioactive material in hallways of buildings

Radioactive material carried or transported into hallways should be in closed containers with tight-fitting lids. The RSO must approve exceptions to this policy.

Section seven: Disposal of radioactive waste

7.1 Solid radioactive waste

EHS personnel place solid waste containers in each posted laboratory. The container is marked with the words "Radioactive Waste" or "Radioactive Material" prominently displayed on the side and lid of the container. Solid radioactive waste may be placed in these containers, including damp paper and solid containers with residual moisture on the surfaces. Test tubes and vials containing pourable quantities of radioactive liquid must be emptied before placing them in solid waste containers.

7.2 Liquid radioactive waste

Polyethylene containers are available for the disposal of liquid radioactive waste. These containers should be placed in an outer container such as a plastic dishpan marked with a radioactive warning label with the words “Radioactive Material” or “Radioactive Waste.”

Care must be taken when disposing of radioactive liquid not to contaminate the side of the containers. Users must not dispose of radioactive waste in sinks.

7.3 Scintillation vials

Liquid scintillation vials should not be disposed of as either solid or liquid radioactive waste. Liquid scintillation vials should be segregated into two groups:

- Vials containing only ^{3}H or ^{14}C in scintillation fluid.
- Vials containing any other isotopes in scintillation fluid.

Vials may be packaged for disposal in the original cardboard racks supplied by the vial manufacturer or placed into containers provided by the Office of Radiation Safety. Do not place any liquid-filled vials into solid radioactive waste containers. Do not dispose of scintillation fluid in sinks.

7.4 Animal carcasses

All animal carcasses and tissue samples containing radioactive material are securely fastened in strong plastic bags. A radioactive carcass tag indicating the date of disposal, responsible investigator, nuclide and its activity must be attached to the bag. The carcasses are then placed in a laboratory freezer until removed by EHS.

7.5 Waste documentation

Users on the nuclides and activity of the waste in all solid, liquid and scintillation waste containers should keep current records. Before the RSO or EHS personnel pick up waste, a waste documentation tag must be attached to the container, giving nuclides and their activities, the responsible sub-licensee and the information on the card.

7.6 Mixed radioactive and hazardous wastes

Occasionally radioactive wastes will contain hazardous wastes as defined by EHS. This includes xylene and toluene-based liquid scintillation fluids. The presence of hazardous wastes and radioactive nuclides must be noted on the waste documentation card.

Users anticipating the generation of these mixed wastes should bring these plans to the attention of the RSO as soon as possible.

7.7 Waste pickup from laboratories

Radioactive waste is picked up and taken to the campus processing facility by EHS personnel. Contact EHS for the removal of any radioactive waste at 480-965-1823. Campus-wide pickup of radioactive waste is usually performed weekly, but extra containers are generally available at the EHS office anytime during daytime office hours.

Section eight: Radioactive material with animals

8.1 General procedures

Special care must be taken when using radioactive material with laboratory animals to ensure that all conditions of the sub-license under which work is conducted are followed.

Secretions from animals administered radioactive material should be considered to be radioactive. Precautions should be taken to prevent contamination of facility surfaces and personnel handling the animals.

Animals to which radioactive material has been administered must be attended to at all times during experimental procedures. These animals must be housed in the ASU Laboratory Animal Care Facilities unless specific approval for alternative housing has been obtained from the ASU Radiation Safety Committee.

8.2 Housing of animals in laboratory animal care facilities

EHS and the Laboratory Animal Care Facilities must be notified before administering radioactive material to animals to be housed in the LACF.

All cages containing animals to which radioactive material has been administered must be labeled with radioactive warning tape. Labels will include the name of the responsible investigator; the nuclide helped and activity administered, and the administration date.

Excretions and bedding from animals administered radioactive material will be considered radioactive and disposed of as radioactive waste.

LACF personnel handling animals administered radioactive material, collecting waste or cleaning cages must receive training in subjects listed in paragraph 2.2.1 and specific techniques for handling animals containing radioactive material.

Section nine: Health physics emergency procedures

Health physics emergencies in laboratories utilizing radioactive material will usually be limited to minor spills. The potential does exist, however, for emergencies involving the creation of significant radiation hazards. Injuries to personnel may complicate these incidents.

In all emergencies, the primary concern must always be the protection of personnel from radiation and non-radiation hazards. The secondary problem is to confine the contamination. Medical assistance should not be withheld or delayed because of the contamination of personnel by radioactive material.

9.1 Minor spills involving no radiation hazard to personnel

1. Notify all other persons in the room at once.
2. Confine the spill immediately, but do not attempt to clean up the spill.
    a. For liquid spills, don protective gloves and place absorbent paper on the spill.
    b. For dry spills, don protective gloves and lightly place moistened absorbent paper on the spill, taking care not to spread contamination.
3. If the spill is on the skin, flush thoroughly with water. If the spill is on the clothing, discard the outer clothing at once.

4. Notify EHS immediately.

EHS	8 a.m.–5 p.m., Monday through Friday.	480-965-1823
DPS	Nights or weekends.	480-965-3456
Fire department	Do not dial 8.	911

5. Permit no one to resume work in the area or leave the premises without the approval of the RSO or their designated representative.

9.2 Accidents involving radioactive dusts, mists, fumes, organic vapors and gases

1. Notify all personnel to vacate the room immediately.
2. Hold your breath, close all windows and escape valves and switch off circulating air.
3. Vacate the room.
4. Alert the RSO and EHS at once.
5. Ascertain that all doors giving access to the room are closed and locked. If necessary, post guards to prevent accidental opening of doors.
6. Do not re-enter the room or permit anyone to leave the premises until approval from the RSO or their designated representative is obtained.

9.3 Injuries to personnel involving radiation hazards

1. Wash minor wounds immediately under running water.
2. Report all radiation accidents, such as wounds, over-exposure, ingestion, inhalation, etc., to the RSO and EHS immediately.
3. Call a physician as needed.
4. Do not permit personnel involved in a radiation injury incident to return to work or leave the premises without the approval of the RSO or the physician.

9.4 Fires

1. Use routine fire emergency procedures to control the fire and evacuate personnel.
2. Notify the RSO or EHS immediately.