



Radiation Safety Manual

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Environmental Health and Safety

UNIVERSITY OF COLORADO

DENVER | ANSCHUTZ MEDICAL CAMPUS



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Section I: Purpose and Scope

1.1 Purpose

The university *Radiation Safety Manual* establishes and defines the university's Radiation Safety Program and serves as the principal document submitted in support of the university's applications for radioactive materials licenses. The *Manual* serves as an institutional policy document, and the policies and procedures set forth herein are imbued with the authority of both:

- The Office of the Chancellor, through the offices of the university CIR (Committee on Ionizing Radiation), and
- The Colorado Department of Public Health and Environment (CDPHE), through that Department's licensing of CU Denver | Anschutz.

1.2 Scope

This Manual, along with its appendices and supplements, is intended to serve as a comprehensive reference document for all persons using or regulating the use of radioactive materials at the University of Colorado Denver | Anschutz (UCD) including:

- Authorized Principal Investigators and all persons using radioactive materials under the auspices of their authorizations from the university CIR,
- Authorized users and all persons using radioactive materials under the auspices of their authorizations from the university HUCIR,
- Members of the university CIR, and
- Staff of the university Environmental Health and Safety Department.

Where applicable distinction between Principal Investigator (PI) and Authorized User (AU) is made; otherwise, all conditions in this manual apply to **BOTH PI's and AU's**.

It is expected that each authorized PI will have this manual readily available for ALL persons who are authorized to be present in the PI's laboratories. Electronic copies are acceptable if they can be easily accessed when needed.

1.3 Revisions



Because the Radiation Safety Manual contains policies and procedures on which the issuance of the university's radioactive materials license is predicated, the revision of the manual is a major undertaking. Minor edits to the manual that do not require submission to CDPHE will be listed below and communicated to all necessary parties through email.



Section II: Licensing and Regulations

2.1 Regulations

The Colorado Radiation program receives its authority to regulate sources of radiation through state statute, known as the Radiation Control Act, in Title 25 Article 11. The Colorado Radiation program's licensing authority is derived from an agreement with the U.S Nuclear Regulatory Commission.

2.2 Radioactive Material Licensing

The university has been issued a medical broad-scope license by the CDPHE, which allows the university a prodigious breadth of discretion in the use of radioactive materials. Among other things, the university is licensed for a great variety of radioactive materials and is given the discretion to internally review and approve:

- New users of radioactive materials (Authorized Users, authorized Principal Investigators and Radiation Workers),
- New uses of radioactive materials (highly variable types of experiments, including use in animals and administration to human research subjects), and
- New facilities and equipment for the use of radioactive materials at the university's authorized locations of use.

The issuance of such a license is predicated on the idea that the university has available among its staff and faculty the appropriate expertise and has created appropriate administrative mechanisms in its institutional structure to assure the licensing agencies that radioactive materials will be procured, used, and disposed of in a safe and proper manner that complies with all applicable regulatory requirements.

2.2.1 Broad Scope License

The university has been licensed by the CDPHE to receive, possess, use, and transfer radioactive materials as designated by license **No. CO 835-01**. This license is subject to all applicable rules, regulations, and orders now or hereafter in effect of the CDPHE, and to all conditions specified in the license document. This license includes locations of use at our two main campuses (CU Denver Campus in downtown Denver and the CU Anschutz Medical Campus in Aurora) and at several satellite locations listed on the license. A copy of the



medical broad-scope license is provided as Appendix A or through the Environmental Health and Safety office at 303-724-0345.

2.2.2 Inspections

The university is subject to inspections every two years by the Radiation Control Division of the CDPHE to ensure that all requirements of the license are being met. These inspections are very thorough, including monitoring checks of laboratory areas, inspection of procurement and disposition records, inspection of records of laboratory monitoring by the principal investigator, inspection of records of the qualifications of individual users, review of records of personnel monitoring and records of administrations to patients. Violations of license requirements can result in a variety of enforcement actions, including fines and suspension or revocation of the license.

2.2.3 University of Colorado Hospital (UCH) License

The University of Colorado Hospital is a separate entity from the University of Colorado Denver|Anschutz and as such has its own radioactive material license (**CO 828-01**). UCH maintains its own separate radiation protection program with its own Radiation Safety Committee and Radiation Safety Officer (RSO). The UCH license governs all activities taking place in the UCH facilities. Activities taking place in all other buildings on the CU Anschutz campus, including buildings contiguous with the UCH buildings, are governed by the University of Colorado Denver|Anschutz license.

2.2.3.1 Joint Projects Involving UCH and UCD

Research or other projects that involve activities both within the UCH buildings and elsewhere on campus will typically require approvals from both institutions' radiation safety committees and may require that radioactive materials be transferred from one license to the other by appropriate paperwork when they pass across the geographical boundaries. Radiation Safety should be consulted as far in advance as possible when such projects or transfers of radioactive materials are contemplated.



Section III: Program Administration and Responsibilities

The CU Denver | Anschutz license is contingent upon the existence of a radiation safety committee, the **Committee on Ionizing Radiation (CIR and HuCIR)** and a radiation safety organization which shall consist of a **Radiation Safety Officer (RSO)** and an **Environmental Health and Safety Department (EHS)**.

3.1. Committee on Ionizing Radiation

3.1.1. Authority and Responsibilities

- **Authority**

The CIR is established by the institution, under the authority of the Office of Vice Chancellor for Research. The CIR, as the institutional radiation safety committee, must conform to Part 3.11.2.3 of the Code of Colorado Regulations (CCR) 1007-1, which describes the requirements for a Type A license of broad scope, and Part 7.8 and Part 7.9 of the same regulations, which describe the requirements for a medical license.

The CIR fulfills the regulatory obligations of the radiation safety committee, while the Human Use Committee on Ionizing Radiation (HuCIR) focuses on the safe use of ionizing radiation in the healing arts. The HuCIR is established by the institution, under the authority of the Office of Vice Chancellor for Research, to provide subject matter expertise in human use of ionizing radiation in the healing arts. The membership and function of both committees is such that all regulatory requirements are met for their respective areas of authority.

- **Responsibilities**

- **Membership**

- The Chancellor, Vice Chancellor for Research, or Dean of the School of Medicine shall appoint **no fewer than three but no more than nine** members from the Faculty and shall designate a Chairperson.
 - Chairperson, preferably, shall have served at least one year on the CIR.
 - No division shall be represented by more than two Committee members.



- If possible, one half of the membership shall be basic scientists and the other half clinicians.
- The normal term of the appointment shall be three years.
- Reappointments shall not be made until at least two years have elapsed.
- Consistent with Part 7.8. of the 6 CCR 1007-1, the Chancellor, Vice Chancellor for Research, Associate Vice Chancellor for Regulatory Compliance or Dean of the School of Medicine appoints an official, such as the Associate Dean for Research Affairs, to serve as the management representative to the Committee.

- **Establishment and Staffing of a Radiation Safety Program**

The CIR shall arrange for the hiring of such personnel as may be necessary for efficient operation of a radiation safety program. A consultant skilled in matters of radiation protection shall be designated by the Committee to supervise its employees on a day-to-day basis and to assist users who require advice on matters of protection, exposure calculations, etc. This individual shall be an ex-official member of the committee.

- **Meetings**

- The Committee shall formally meet as often as required, but not less than 4 times every calendar year.
- Minutes will be maintained and kept on file for review and inspection.
- The Committee shall, through available institutional resources such as email or EHSA, review all applications from Principal Investigators for authorizations for the procurement of radioactive materials as required.

- **CIR Review of Application to Procure and Use Radioactive Materials**

- **Initial Review of Application by EHS**

- EHS will provide an initial review of each application to assess its basic conformance to Committee requirements.
- Completed applications must be submitted through EHSA and contain all the required information.
- EHS reviewers will supply specific technical and regulatory reference information and calculations as needed for both the applicant and the Committee.



- If no response to the initial review and any subsequent communication is received by EHS within 45 days the application will be inactivated and a new application will be required.
- **Actions to be Taken by Reviewers**
 - The committee coordinator will notify the Committee that the application is ready for review.
 - Members shall vote on each application by approving, disapproving, or conditionally approving (e.g. maybe, yes provided that) with appropriate comments, WITHIN TEN BUSINESS DAYS.
 - The Committee may authorize the A/RSO to determine the adequacy of applicants' responses to *conditional approvals* (maybe)
 - Responses to disapprovals must be resubmitted through EHSA.
- **Committee's Approval of an Application**
 - EHS will process the application after the ten-day voting period and/or when a majority of reviewer responses have been received.
 - Reviewer comments received after the ten-day deadline will be considered but will not be allowed to delay the application process further.
 - If any questions or concerns are raised with the application, approval will be withheld until those are adequately addressed.
 - If response to a reviewer's remark or any subsequent communication is not received by EHS within 45 days the application will be inactivated, and a new application will be required to be submitted.
- **Issuance of Authorization to the Applicant**
 - Once an application is approved, EHS staff will email the authorization electronically and issue a written authorization to the PI, which will be signed by the chairperson and the RSO and will summarize constraints and conditions on the applicant's use of radioactive materials.
- **Rulings and Actions by the Committee**
 - The CIR shall have the authority to make final judgments and take actions relative to any situation involving ionizing radiation.



- Reports by the RSO or other employees of the Environmental Health and Safety Department will be forwarded to the Committee with recommendations.
- The Committee shall have the authority to revoke or suspend any authorization for cause, and the authority to change the conditions of existing authorizations at any time, based on any new information that may come to the Committee's attention.

3.2. Environmental Health and Safety Department (EHS)

The Radiation Safety Officer (RSO) and the Radiation Safety Staff are part of the Office of Environmental Health and Safety and are responsible for managing and implementing the university Radiation Safety Program. The RSO and the Radiation Safety Staff will conduct an annual review of the Radiation Safety Program and report its findings to the CIR and EHS director.

3.3. Radiation Safety Officer (RSO) and Radiation Safety Office

3.3.1. Radiation Safety Officer Responsibilities

- **Authority to Impound Material and/or Terminate Use**
 - **Non-Compliance**

The Radiation Safety Officer has the authority to immediately impound and/or terminate the use of radiation that is found to be a threat to health, safety, or property; or considered to be out of compliance with regulations or license conditions.
 - **Improper Authorization**

The Radiation Safety Officer has the authority to impound and/or prevent the use of any radiation source or radioactive material that either the Radiation Safety Officer or Radiation Safety Committee has not properly authorized.
- **Administration**



- Manage the administrative aspects of the Radiation Safety Office (RSO), and Radiation Safety program under general direction of the Director of Environmental Health and Safety (EHS).
- Supervise the RS staff, including offering recommendations to the Director of EHS on hiring, promotion, and disciplinary action, and conducting performance evaluations.

- **Advising EHS Director**
 - Advise the Director of EHS on the status of the radiation safety program.
 - Recommend actions necessary to maintain the program in full compliance with regulations and license conditions.
 - Provide reports and plans as necessary to Director of EHS

- **Annual Report**
 - Provide an annual report to the Radiation Safety Committee that covers the radiation safety program activities for the previous year.

- **Approving Radiation Use**
 - Approve the safe use of radiation within the limits of the authority granted by the Radiation Safety Committee.

- **Radiation Safety Manual and Procedures**
 - Revise and maintain the Radiation Safety Manual and Radiation Safety procedures for the radiation safety program as necessary.

- **Compliance**
 - Determine and maintain compliance with rules and regulations, license conditions and any conditions set forth by the Radiation Safety Committee.
 - Review and submit applications for the use of radioactive material to the Radiation Safety Committee.
 - Prepare all applications for license amendments and renewals and negotiate terms of license conditions in the best interest of the University.



- **General Surveillance**

- Maintain general surveillance of overall radiation safety activities involving radiation machines and radioactive materials, including routine monitoring and special surveys of all areas where radiation work is done.

- **Personnel Monitoring**

- Distribute and arrange for processing of personnel monitoring devices.
- Determine the need for and evaluation of bioassays.
- Keep personnel exposure and bioassay records.
- Notify individuals and their supervisors of exposures approaching maximum permissible amounts and recommend actions if needed.
- Maintain and enforce the university ALARA program.

- **Sealed Sources**

- Conduct and supervise leak tests and maintain inventory of sealed sources.

- **Training**

- Develop and maintain training programs that instruct personnel in the proper procedures for the safe use of radioactive materials on campus.

- **Consulting**

- Provide consulting services on all aspects of radiation protection to personnel at all levels of responsibility.

- **Records**

- Maintain all records as required by the University's Radioactive Material license and as required by University of Colorado Denver|Anschutz administration.

3.3.2. Radiation Safety Office



- **Personnel Monitoring and Bioassay**

- Radiation Safety provides dosimeters to measure total integrated external radiation dose to the whole body and/or designated extremities. These dosimeters are obtained from a commercial supplier.
- As required by the Radiation Control Division of the CDPHE, no personal dosimeter will be issued by Radiation Safety until the wearer has completed the applicable training and testing requirements described in section 4.2.1 of this Manual.
- Under very limited circumstances, the RSO may issue a dosimeter to individuals occupying spaces surrounding areas where large amounts of radioactive materials are being used. These badges are issued on a case-by-case basis and only the RSO can exempt these individuals from completing the training.
- Radiation Safety has in-house capability to provide all routine types of bioassay measurements that are required by the license, to assess intakes of radioactive material and resulting *internal* radiation doses.
 - This includes urine bioassay and direct *in vivo* measurement of radiation emitted by radioiodine in the thyroid.
 - The RSO will identify cases that require a bioassay when they occur and will make appropriate arrangements to obtain the necessary bioassay information.
- All records pertaining to personnel dosimetry and bioassay are maintained by Radiation Safety, and Radiation Safety responds to requests for exposure histories from employers of former university personnel, upon submission of a signed release from the effected individual. All requests regarding dosimetry and bioassays should be sent to raddosimetry@cuanschutz.edu.

- **Radioactive Package Receiving**

- Radiation Safety performs package receiving procedures on all packages of radioactive materials coming onto campus to accomplish the following functions:
 - Check if the package is damaged or leaking, and
 - Measure the radiation exposure rates due to penetrating (x and gamma) radiations emitted by the package and ensure that they are within the limits set by the U.S. Department of Transportation



- Provide appropriate information about measured exposure rates to person(s) who will handle the package, and
 - Ensure that the outside surfaces of the package are free of radioactive contamination, and that the package is otherwise suitable for transfer to the laboratory staff on campus, and
 - Record all necessary initial information into EHSA to maintain inventory.
- **Radioactive Materials Inventory Control and Tracking**
 - Radiation Safety maintains a centralized radioactive materials inventory system as required by the radioactive materials license.
 - This system allows the RSO to exercise approval authority over all acquisitions of radioactive material, to ensure that the type and amount of radioactive material being acquired is consistent with the radioactive material license and the PI's authorizations.
 - Incoming packages of radioactive materials are logged into EHSA upon receipt to the EHS storage facility. Accounting information and waste tickets are provided by Radiation Safety to laboratories prior to delivery.
- **Calibration of Survey Instruments**
 - Radiation Safety can perform almost all calibrations of portable radiation survey instruments required by the institutional license.
 - Calibrations are performed annually or as needed if maintenance or repairs are performed.
 - Radiation safety can provide loaner instruments to laboratories while the permanent portable instrument is being calibrated.
 - Instruments that cannot be calibrated or repaired by Radiation Safety are serviced by an outside provider.
- **Leak Testing of Sealed Sources**
 - Radiation Safety maintains inventory and performs required leak testing of sealed radioactive sources on campus.
 - Radiation Safety can also perform leak testing on generally licensed equipment if required.



- **Radiation Protection Surveys**

- Radiation Safety can perform radiation protection surveys to evaluate contamination of laboratory surfaces and dose rates due to sources of radioactive material in lab spaces. Contamination surveys are typically performed by Radiation Safety for the following:
 - When laboratory areas or major items of laboratory equipment are being moved, or decommissioned and returned to general use not including radioactive materials,
 - During routine laboratory audits
 - As a follow-up to a radioactive spill or contamination incident, or
 - As part of a spot check program as directed by the CIR
 - In all cases, Radiation Safety contamination surveys are confirmatory in nature and do not replace or lessen the need for the contamination surveys that are required in each radioactive material authorization.
- Laboratories are encouraged to request contamination surveys or dose rate measurements from Radiation Safety whenever they feel they are necessary.

- **Disposal of Radioactive Waste**

- Radiation Safety provides disposal services for all radioactive and mixed radioactive wastes generated by research laboratories on the CU Denver | Anschutz campuses and at some satellite locations.
- Radiation Safety picks up wastes at the point of generation (at the laboratory).
 - Contact Radiation Safety by calling 303-724-0109 or by completing the waste pickup request form and emailing rad.waste@cuanschutz.edu to schedule a waste pickup.
- Radiation Safety also provides containers, waste bags (for purchase), and other packaging materials for radioactive wastes, including the standard items required by university policy.
- Additional waste requirements are described briefly in section 4.2.7 below.

- **Shipping Radioactive Materials**



- Radiation Safety ships some radioactive waste to offsite locations for processing and disposal.
- Any plans to ship radioactive material to an off-campus location require Radiation Safety review and RSO approval before being shipped out.

- **Training**
 - Radiation Safety provides the training and testing required for Principal Investigators and other people who will work with radioactive materials.
 - The training and testing provided by Radiation Safety does not replace or lessen the need for the specific on-the-job related instruction that Principal Investigators are required to provide, as discussed in section 4.2.1 below.
 - Radiation Safety provides online refresher training for Principal Investigators and Radiation Workers.
 - Radiation Safety refresher training is required annually for all Principal Investigators and Radiation Workers actively possessing and using radioactive materials.
 - Radiation Safety will send reminders when annual refresher training is due via email.
 - If any PI or Radiation Worker is found to be delinquent in this requirement, the RSO may suspend all the associated PI's authorizations until the refresher training course is completed.

- **Consultation**
 - Radiation Safety staff professionals are always available to researchers for advice and consultation in matters related to radiation safety.
 - Radiation Safety maintains access to a variety of printed and electronic resources that may be helpful to researchers.
 - Radiation Safety staff time will need to be scheduled in accordance with other workload priorities, especially in matters requiring extensive effort such as assistance in preparing applications for complicated or unusual experimental protocols.

- **Emergency Response**



- Radiation Safety responds to all emergencies and incidents involving radioactive materials used by researchers.
- Radiation Safety maintains shower areas at the EHS Support Facility which can be made available as a decontamination area for cases of skin contamination.
- Refer to Section V for contact information and steps to follow if an emergency occurs.

3.4. Authorized Users and Principal Investigators

3.4.1. Principal Investigators

A Principal Investigator (PI) must be a faculty member with training and/or experience appropriate to the type of investigative procedure involving radioactive materials as requested on the application and **MUST COMPLETE** the required training administered by the Environmental Health and Safety Department. CU Denver | Anschutz does not accept training received at other institutions in lieu of the university's mandatory minimum requirements.

A faculty member who, in the Committee's judgment, does not meet all of the appropriate qualifications of training and experience in the relevant uses of radioactive materials must first complete the university's training requirements for PI's and may then be issued a provisional authorization under the supervision of an authorized Principal Investigator, who shall serve as a preceptor, for a period to be determined by the Committee. After the prescribed period has elapsed, a formal request for review can be initiated by the faculty member desiring the autonomous status of "authorized Principal Investigator."

● Responsibilities

- The authorized PI is responsible for assuring the safe and proper use and disposal of all materials obtained under their authorization and for ensuring compliance with all of the requirements of this manual and other institutional policies and procedures documented in EHS publications.
- The authorized PI is bound by the terms and conditions of the authorization as issued and administered by Radiation Safety under the CIR's authority, and by all of the representations and commitments that were made to the CIR in order to obtain the authorization.
- All persons named as coinvestigators or radiation workers are subject to the authority of the authorized PI in matters pertaining to the procurement of



radioactive materials under the authorization and the safe and proper use and disposal of those materials.

- The authorized PI must ensure that all required training is completed and maintained by laboratory personnel prior to any project utilizing radioactive materials, wherein that person may use or affect the use radioactive materials. Failure to comply with this requirement will result in action by the CIR.
- Authorized PIs are responsible for the implementation of any controls required by the CIR because of reported doses exceeding ALARA levels.

3.4.2. Authorized Users

Credentialed physicians granted authorization in writing by the Committee on Ionizing Radiation as Authorized Users of radioactive. These individuals must meet the criteria listed in 6 CCR 1007-1 Part 7 Appendices 7D or 7E. All medical use of radioactive materials is under the supervision of an AU.

- **Responsibilities**

- Provide proper instructions in all policies, regulations, and license conditions to individuals authorized to use RAM under the AU authorization.
- AU must ensure compliance with the CDPHE rules and regulations pertaining to radiation control, CU Denver | Anschutz policies and procedures, and the conditions of the CU Denver | Anschutz Radioactive Materials License.
- If required, AU must be physically present; otherwise, AU must be available by phone within ten (10) minutes to communicate with the supervised individual.
- AU is responsible for reporting to the Radiation Safety Officer any unusual incidents including theft or loss of radioactive materials, major spills, or misadministrations as outlined in 6 CCR 1007 Part 7.21.
- The AU is fully responsible for the acts and omissions of supervised individuals.

3.5. The University As Low As Reasonable Achievable (ALARA) Program

CU Denver | Anschutz is committed to maintaining employees' radiation exposures As Low As Reasonably Achievable (ALARA) below the occupational limit. Radiation workers are expected to take an active role in maintaining their exposures ALARA.



The potential adverse health effects of low-level radiation exposure, specifically, increased risk of carcinogenesis and/or genetic defects in future generations, is considered by the regulatory agencies to be a non-threshold phenomenon. The occupational dose limit is not a simple line of demarcation between “safe” and “unsafe” or “harmless” and “harmful” radiation doses. The risk of any radiation exposure, including those less than the less than the occupational dose limit, decreases with the magnitude of the exposure. Doses less than the occupational dose limit carry risks that are considered for purposes of regulatory policy to be very small but NOT non-existent. These considerations define the rationale for maintaining radiation exposures ALARA, to avoid any unnecessary risk, no matter how small.

Biomedical research, in contrast to clinical radiology, rarely involves working with sources of penetrating radiation that are likely to deliver doses that exceed the ALARA limits. Correspondingly, very few such reports are seen, and dose reports substantially exceeding the ALARA limits are usually attributable to a misuse of the dosimeter or an artifact of the reporting process. The emphasis in the university’s program is placed upon:

- Thoroughly investigating those few dose reports that do exceed ALARA levels, and
- Promoting informational and educational communications to radioactive materials users minimizes the likelihood that a significant dose will be received by self-contamination (internal dose), which is the greater hazard in the biomedical research setting.

3.5.2. Radiation Safety Officer’s Review of Bioassay and Dosimetry Results

3.5.2.1 Bioassay

For laboratory procedures conforming to the training and hygiene requirements of this Manual and not involving volatile forms of radioactive material, bioassay for a given radionuclide may be required if there is a potential for an intake of radioactive material that would result in a dose that is greater than 10% of the applicable occupational dose limit.

- Bioassay is required after each labeling for all persons performing radioiodine labeling reactions, regardless of the amounts involved.



- For all situations involving volatile forms of radioactive material, other than radioiodine labeling reactions, the requirement for bioassay will be determined by the CIR on a case-by-case basis.
- Apart from the specific requirement for radioiodine labeling, the scheduling of bioassay measurements will be determined individually on a case-by-case basis by the RSO in consultation with the Principal Investigator, the affected individual, and, if appropriate, the CIR and Occupational Health Program.

3.5.2.2 Dosimetry

- The Occupational Dose Limits are published by the CDPHE, under Part 4.6, "Occupational Dose Limits for Adults", in the Colorado Rules and Regulations Pertaining to Radiation Control 6 CCR 1007-1. These limits are all in the form of annual, rather than quarterly, limits, and they require summation of doses from both internal and external sources.
 - Doses from external sources are taken directly from the reported doses on personal monitors.
 - Doses from internal sources are calculated when bioassay measurements indicate the presence of some measurable amount of radionuclide in a worker's body.
- The RSO reviews each monthly or quarterly dosimetry report as it comes in from the vendor and performs comparisons for the ALARA Program simultaneously. Monthly dosimeters use comparisons based on the cumulative quarterly totals that have been reported to date. Results reported for quarterly dosimeters are simply compared directly to the quarterly limits.
 - The ALARA limits are:
 - Level I: one tenth of one quarter of the applicable annual Occupational Dose Limit and
 - Level II: three tenths of one quarter of the applicable annual Occupational Dose Limit.



Table 1: Applied Annual Occupational* Dose Limits for Adults and Related ALARA Reporting Levels for Cumulative Quarterly Totals (mrems)**

Part of Body	Annual Occupational Dose Limit	Quarterly ALARA Level I Limit	Quarterly ALARA Level II Limit
Whole Body ¹	5,000	125	375
Skin of Whole Body ²	50,000	1,250	3,750
Extremity ³	50,000	1,250	3,750
Lens of Eye ⁴	15,000	375	1,125

*These limits apply to *radiation workers* who are trained, have passed the Radiation Safety Certification Examination administered by EHS, and are being regularly monitored with a whole body/TLD dosimeter. *Persons who do not meet these criteria must be considered members of the public*, and much stricter criteria (e.g., an Annual Dose limit of 100 mrems' total effective whole-body dose equivalent) are applicable.

**These limits apply to ADULTS ONLY - *the limits for minors are one tenth of those shown* in the table. The Occupational Dose Limit for fetal dose to *declared*-pregnant workers is "500 mrems over the full term of gestation, acquired at a more or less steady rate," and reported fetal doses in excess of 10 mrems in any month are generally reported to the declared-pregnant worker and investigated by the RSO.

¹e.g, deep dose reported on the whole-body dosimeter.
²e.g., shallow dose reported on the whole-body dosimeter.
³e.g., finger dose reported on a ring dosimeter.
⁴e.g., eye dose when reported separately on an eyeglass dosimeter.

- All reports of doses exceeding ALARA limits are reported to the affected individual in writing and are investigated by the RSO, who seeks to determine their seriousness, depending on magnitude and cause.
- For Level II dose reports, the affected individual is required to reply in writing to the RSO regarding the circumstances that may have created the dose report.
- The RSO may also seek to determine whether the worker's exposure could be reduced by reasonable and economical changes in procedures, facilities, or equipment, and may make corresponding recommendations to the PI.
- All reported doses exceeding ALARA levels are reported to the CIR by the RSO and are discussed at the CIR's quarterly meetings. At its discretion, the CIR may choose to address problem situations individually and/or at the program level.



Section IV: Radioactive Material Authorization and Laboratory Responsibilities

4.1 Radioactive Material Authorization

To begin the application process for a radioactive material authorization email radappnh@cuanschutz.edu for Non-Human use or radapphu@cuanschutz.edu for Human use. Instructions for how to start an application through our online system, EHSA, will be given.

4.1.1 Conditions Requiring a New Radioactive Materials Authorization

There are various situations that occur in practice, in which a new application to the Committee is required. This list is not necessarily exhaustive with respect to situations in which the Committee may decide that a new application is required. Consult Radiation Safety for advice when you are unclear if a new application is required.

4.1.1.1 Operations Outside of Authorized Principal Investigator's Usual Facilities

If an authorized PI wishes to conduct a new experiment or procedure in a new location that is not in the immediate span of control of that PI a new authorization will be required to use radioactive materials in that location. PI's should consult with Radiation Safety to determine if a new authorization is required when planning to perform an experiment in a new lab space that is not located near any currently approved lab space.

4.1.1.2 New Type of Experiment

If an authorized PI proposes a new use of radioactive materials (i.e., a new type of experiment) that is significantly different than the use(s) for which that PI is currently authorized by the Committee, then new application is required. Investigators who have questions about specific situations should consult Radiation Safety to determine if/when a new application is required.



4.1.1.3 Previous Authorization Expired

Once an authorization has passed its expiration date no materials may be procured under that authorization and any continuance of previously authorized work requires submittal of a new complete application rather than a short renewal application. Principal Investigator’s should make note of this when considering renewal and when tracking expiration dates of currently held authorizations.

4.1.2 Hazard Classification

The hazard classification for an authorization are based on the CDPHE Annual Limits on Intake (ALI) of the specific isotope being used, and the chemical compound being used in the laboratory.

- The hazard classification for a given laboratory room or suite authorized for radioactive materials is the highest rating associated with any authorization that is currently approved for that area.
- The hazard ratings of a PI’s authorizations will be used to determine frequencies of radiation safety audits, frequencies of contamination surveys, and other parameters that may apply at the discretion of the RSO and CIR.
- A complete list of ALI’s for isotopes currently used at the university is provided in Appendix I

Laboratory Hazard Classification		
Low	Medium	High
< 0.1*ALI	≥ 0.1*ALI and < ALI	≥ ALI

Hazard Classification	Audit Frequency	Survey Frequency
Low	Every 2 Years	Monthly
Medium	Every 2 Years	Weekly
High	Annual	Daily



4.1.3 Renewing an Authorization

Radioactive materials authorizations issued to PIs by the CIR carry maximum terms of:

- Two years for High hazard level,
- Three years for Medium hazard level, and
- Three years for Low hazard level.

Any authorization that has exceeded these terms requires a short renewal application to the CIR, to be processed in the same manner as new applications, as described above.

- PIs will be notified via e-mail approximately 90 days prior to the authorization expiration date.

4.1.4 Expired Authorization

NO RADIOACTIVE MATERIALS may be held at CU Denver | Anschutz without a current and active RAM authorization approved by the CIR.

- A 30-day grace period may be granted to the PI to prepare a new application and retain the materials.
- Once that grace period has lapsed Radiation Safety will confiscate the materials under the authority of the CIR.
If no application is received within 30 days of confiscating the material, the material will be disposed of by Radiation Safety.

4.1.5 Closing an Authorization

Contact Radiation Safety as soon as it is known that an authorization will be closed. Radiation safety will pick up any remaining radioactive materials including unused stock vials and review the last area surveys of the lab space.

- It is the responsibility of the PI to perform final area surveys and equipment surveys.
- Radiation Safety may elect to perform additional confirmatory surveys.
- Once surveys are approved equipment should be green tagged for disposal through normal channels.
- Radiation Safety will remove all labels and take all provided waste storage containers upon final survey approval.



Closing an authorization is final. If the PI wants to open a closed authorization, the process for opening a new authorization must be followed.

4.2 Laboratory Responsibilities

4.2.1 Training and Qualifications

4.2.1.1 Required Training

All persons approved to work with radioactive materials on the CU Denver | Anschutz Campus must complete:

- CU Radiation Safety Initial Training (Part I) on Skillsoft
 - Administrative personnel who will only be ordering radioactive material through the vendor but not working with the material only need to take this initial training.
- Radiation Worker Training – Part II in-person with Radiation Safety staff
 - PIs must complete an additional PI training at the end of Radiation Worker Training – Part II
- On-the-Job Training (OJT) specific to each lab and the experiment being conducted.
 - Initial OJT is conducted with Radiation Safety staff upon receipt of the first order of radioactive material to the laboratory.
 - After the initial OJT lab staff is expected to perform OJT for all new staff approved for radioactive material use.
 - PIs must also complete OJT even if they do not plan on physically doing work in the lab.

For individuals that are coordinating human research studies involving ionizing radiation but will not be directly working with sources of ionizing radiation, the required training is radiation safety awareness training for the Research Imaging Center. This training will be provided by the RSO or designee and will address all radiation hazards associated with human use studies at the facility.

4.2.1.2 Training Refresher

- Radiation Safety Training will be renewed annually via Skillsoft. Radiation workers will receive an email reminding them to renew their training. All



listed workers on an active authorization, including the PI, must maintain their training requirements and failure to complete the annual refresher training may result in radioactive materials being withheld from the laboratory.

- OJT will be refreshed with laboratory staff during the laboratory's Radioactive Material Audit.

4.2.1.3 Use of Radioactive Materials by Minors

Any minor (person of age less than eighteen years) who will work directly with radioactive materials, or whose activities might be reasonably expected to present a possibility of contact with potentially contaminated surfaces or other radiation-related hazards, must obtain permission from the RSO.

The use of radioactive materials by minors is generally discouraged, even if such use occurs in the context of a designed educational experience that involves only small amounts of radioactivity. Such minors must certainly meet the training and testing requirement set forth in 4.2.1, and they are deserving of more supervisory attention than older persons. In addition, extremely restrictive Occupational Dose Limits are stipulated by the state and federal regulations for minors.

Individual cases of prospective work by minors should be discussed with the RSO to minimize the likelihood of problems.

4.2.1.4 Issues Related to Pregnancy and Fertility

Issues related to pregnancy and fertility are complicated and fraught with legal implications and should be understood by all persons involved in working with radiation or radioactive materials, both male and female. These issues are treated at length in the EHS Radiation Safety Initial Training.

4.2.2 Labeling

Signs, labels, and other postings perform a particularly valuable function in the university setting, as a means of communicating information to the diverse array of persons who may frequent areas where radioactive materials are stored or used. Proper signs, labels, and postings are an important indication of diligence and good practice on the part of the authorized Principal Investigator.



4.2.2.1 Radioactive Materials Caution Signs

Any space that is subject to containing radioactive materials exceeding the quantities in Appendix II is required by state regulations to be posted with the standard yellow-and-magenta sign bearing the trefoil symbol and the words “Caution: Radioactive Materials.” At CU Denver | Anschutz,

- ALL rooms authorized by the CIR for use or storage of radioactive materials must be so posted, unless a specific exemption is granted (Contact EHS for more information on exemptions).
- Standard laboratory hazard signs provided by EHS are mounted at the corridor entrance(s) to laboratories and include the “Caution: Radioactive Materials” sign when appropriate.
 - These signs may be supplemented on an interim basis by stickers available from EHS.
 - Additional signs at entrances from adjacent areas other than the corridor or hallway may be needed – Radiation Safety should be consulted in specific cases.

4.2.2.2 Radiation Area Caution Signs

Signs bearing the words “Caution: Radiation Area” are different than “Caution: Radioactive Materials” signs, under state and federal regulations.

- “Caution: Radiation Area” signs are to be used to warn of the presence of substantial sources of penetrating photon radiation (gamma and x rays).
- The definition of a “Radiation Area” is “any area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrems (0.05 mSv) in one hour at 30 centimeters from the source of radiation or from any surface that the radiation penetrates” (Colorado Rules and Regulations Pertaining to Radiation Control).
- Such areas should be relatively rare in modern biomedical research, except for some special areas where devices such as irradiators may be housed.



- Any area requiring designation as a “Radiation Area” clearly requires special controls on access to demonstrate compliance with the allowable dose limits affecting members of the public.
- PIs are encouraged to contact Radiation Safety early in the planning stages if non-routine or large quantities of radionuclides are anticipated so that proper posting and area controls may be evaluated.

4.2.2.3 The CDPHE Notice to Workers

The CDPHE publishes a poster entitled “Notice to Workers” that contains legally required information that licensees must post in “a sufficient number of locations to permit individuals engaged in work under the license to observe them on the way to or from any particular work location” where the radioactive materials will be used.

- These postings, along with information about where individuals can review copies of the radioactive materials license and related documents (the offices of EHS) are posted in public areas of buildings on campus that contain areas authorized for radioactive materials.
- PIs and all authorized radiation workers should be familiar with the location of these signs on their floor.
 - Most are located by door to the elevators on floors where radioactive materials are used.

4.2.2.4 The Principal Investigator’s “PI Posting”

Each Principal Investigator authorized for radioactive materials must have their list of authorized workers for each authorization posted in or nearby the area where radioactive materials are being used.

- This list is provided by Radiation Safety whenever a RAM authorization is approved.
- It is the PI’s responsibility to update Radiation Safety whenever there is new radiation worker staff or staff departs the lab.

4.2.2.5 Labeling of Laboratory Appliances and Bench Areas Used for Radioactive Materials

Specific, designated areas within the laboratory that will be used in any manipulation or processing of radioactive materials should be marked and/or



outlined with tape bearing the “Caution: Radioactive Materials” warning or yellow and magenta striped tape provided by Radiation Safety.

- These areas must be treated as being potentially contaminated during periods of use of radioactive materials.
- During extended periods of NO use of radioactive materials, subsequent to a thorough contamination survey demonstrating that these surfaces are not contaminated, the labeling may be removed until the use of radioactive materials is resumed.

Types of areas/equipment to be labeled include:

- Designated portions of benchtops, fume hoods, centrifuges, water baths, hybridization ovens, incubators, and other laboratory appliances, and refrigerators, freezers, and other storage units.
- The extent of these areas should be minimized as a fundamental method of limiting the potential for persons in the laboratory to become contaminated and spread contamination.
 - The representation that every surface in the PI’s authorized area(s) is subject to such use is generally not defensible and does not eliminate the requirement to mark such areas as described in this section.
- Clear and prominent markings are required for sinks used for disposal of 3H

4.2.2.6 Labeling of Containers

The appearance of containers used for radioactive materials, particularly waste containers that will sit on the floor, is critical to minimizing the potential for problems.

- All radioactive trash cans and liquid waste collection containers must be labeled conspicuously on at least two sides with standard yellow-and-magenta “Caution: Radioactive Materials” warning labels that are at least 3x5 inches in size, available from Radiation Safety.
- Principal Investigators are urged to use the standard containers that are provided by Radiation Safety, which are pre-labeled and are chosen and standardized to further minimize the potential for confusion with other waste containers.
- Any container of any type that may contain more than one tenth (1/10) of the amounts of radioactive materials in Appendix II and is not continuously in the control of a trained radiation worker during the



performance of an experiment, must be labeled with tape bearing the “Caution: Radioactive Materials” warning.

4.2.3 Acquiring and Receiving Radioactive Materials

Radioactive materials obtained under the university license are strictly controlled. Users should understand the concept of the audit trail, by which the university, as a licensee, is responsible for tracking the fate of each microCurie (uCi) of radioactive material from “cradle to grave”: from the time of its initial arrival on campus until its ultimate disposal, transfer, or decay is properly documented.

4.2.3.1 Obtaining Prior Approval from Environmental Health and Safety for All Acquisitions

ALL acquisitions of radioactive materials at the university require the PRIOR approval of the RSO, as stipulated by the license.

- Regular purchase requests, including blanket and standing orders, must be approved by the Radiation Safety office prior to their being submitted to Grants and Contracts, Purchasing, or Finance.
- Non-purchase-ordered acquisitions, such as credit card orders, free samples from vendors or materials supplied by collaborating investigators at other institutions, also require prior approval.
 - Contact Radiation Safety for assistance in these cases.
- The same approval process is required for materials that will be delivered directly to a satellite location off campus for use under the university’s license.
- RAM acquired under the UCH license that will be used on campus must also go through the above approval process.
- When CU Denver | Anschutz-administered grant funds are used to purchase RAM through the university purchasing system for use at another institution under the other institution’s radioactive materials license (e.g., University Hospital, the Veterans Administration Hospital, or Children’s Hospital Colorado), the same approval by Radiation Safety is required, but is granted automatically on the authority of the host institution’s RSO, and therefore should be signed off by that officer before being submitted to Radiation Safety. (This requirement is necessary for two reasons: to avoid intractable problems for the CU Denver | Anschutz Purchasing Agent, tracking



purposes, and to assist the RSO of the host institution in exercising the control that that institution's license requires.)

- NO PROCUREMENT OR RECIEPT of radioactive materials will be permitted unless all staff members designated as radiation workers on any of the Principal Investigator's authorizations (including the Principal Investigator) is current on the training requirements set forth in section 4.2.1 of this manual.
 - This includes completion of the annual refresher training.

4.2.3.2 The Principal Investigator's On-hand Possession Limit

For each individual authorization, the Principal Investigator is authorized a specific on-hand possession limit by the CIR, which is a subdivision of the university's overall institutional possession limit.

- The possession limit is the maximum amount that the PI may possess at any one time, including all stock vials and all waste materials that have not yet been properly disposed.
- The RAM Authorization Update form, available on the EHS website, must be submitted to Radiation Safety to request changes to the possession limit.

4.2.3.3 The Principal Investigator's Yearly Acquisition Limit

For each individual authorization, the Principal Investigator is authorized a specific yearly acquisition limit by the CIR that is the maximum amount that the PI may acquire in the calendar year; January 1 through December 31.

- The RAM Authorization Update form, available on the EHS website, must be submitted to Radiation Safety to request changes to the annual limit.

4.2.3.4 Delivery of Radioactive Materials to CU Denver | Anschutz

ALL radioactive materials that arrive on campus from other locations (delivery over a roadway or public thoroughfare) must arrive initially at the EHS Support Facility so that package receiving procedures required by the radioactive materials license can be performed.

Dedicated EHS Package Receipt Addresses:



EHS Support Facility
13178 E. 19th Ave.
Aurora, CO 80045

- Any incoming RAM package that arrives at an on-campus laboratory without passing through the dedicated EHS package receipt location, for whatever reason, must be brought to the attention of Radiation Safety immediately.
- Collaborating investigators at other institutions, or their campus RSOs, that may make radioactive shipments to CU Denver | Anschutz investigators should be informed about this requirement and directed to contact the CU Denver | Anschutz RSO.
- Direct deliveries to listed off-campus satellite locations require specific arrangements with Radiation Safety to ensure that package receiving procedures and RAM inventory system data entry will be properly completed.

4.2.3.5 Transportation of Radioactive Materials on Campus

Transportation on campus does not require the extensive packaging, labeling, marking, shipping papers, and other regulatory items that are required for over-the-road transport. However, as documented below:

- NO transportation over or along public thoroughfares may be performed, and
- Materials must be transported carefully in CLOSED, DURABLE CONTAINERS with due precautions against spillage or leakage such as secondary containment for any liquids.

Transport on campus by laboratory personnel is strongly discouraged and should be avoided whenever possible, due to the extensive problems that may ensue if there is an incident of any kind in which there is a possibility of contamination of floors, elevators, or other surfaces in public areas.

- Contact Radiation Safety prior to transporting any radioactive materials or samples.

4.2.3.6 Transportation of Radioactive Materials To and From Off-Campus Locations



Transportation of radioactive material to off-campus locations requires transport over public roadways, which invokes the regulations of the U.S. Department of Transportation (U.S. DOT) and comparable regulations of the Colorado Department of Public Health and Environment (CDPHE) and the U.S. Nuclear Regulatory Commission (U.S. NRC). Basic regulatory requirements include, but are not limited to, the following:

- Specific types of packaging along with specific markings and labels.
- If the package is to be transported by a commercial carrier, DOT shipping papers must be prepared and other requirements (e.g., security seals) may apply.
- Individuals offering radioactive material for domestic ground shipments must have current DOT shipper training, as outlined in 49 CFR 172, Subpart H.

Investigators contemplating shipments of radioactive material of any type to colleagues at other institutions should contact EHS as early as possible for assistance in meeting the applicable requirements. Radiation Safety will then:

- Contact the RSO of the receiving institution to obtain a copy of that institution's radioactive materials license as required by law and to obtain appropriate shipping instructions,
- Assist the Principal Investigator in preparing the shipment in conformance with the applicable regulations, and
- Properly document the transfer of radioactive material from the CU Denver | Anschutz license to the receiving institution's license.

Any accident involving the transportation of radioactive materials on public roadways or any other location not completely on CU Denver | Anschutz property must be reported IMMEDIATELY to the Colorado Department of Public Health and Environment.

4.2.4 Storage and Security of Radioactive Materials

4.2.4.1 Storing Radioactive Materials

Storage areas should be chosen to be as well-secured and as far away from frequently occupied areas, especially office areas, as possible.



Radioactive materials may be stored or used only in the responsible Principal Investigator's authorized areas that have been registered with Radiation Safety so that EHS's emergency response and other institutional responsibilities under the radioactive materials license may be effectively discharged.

- Principal Investigators considering use of radioactive materials in facilities not previously so authorized should consult the RSO as early as possible in the planning process.

4.2.4.1.1 Designation of Laboratory Areas Authorized for a Principal Investigator's Use

Areas to be authorized for the use or storage of radioactive materials are normally designated by laboratory room and/or hallway numbers on a Principal Investigator's application to the CIR.

- Any addition or deletion of rooms that is not contained on an application to the CIR must be reported to the RSO by submitting the Authorization Update Form.
- Deletion of an authorized Principal Investigator's responsibility for a given space requires the conditions in section 3.4 of this manual to be met.

4.2.4.1.2 Areas Shared by Two or More Principal Investigators

Shared areas, such as rooms that are dedicated to radioactivity counting machines or shared radioactive experiment space, will be listed on all authorizations for all PI's sharing that space.

- Radiation Safety will not become involved in disputes about conditions such as contamination that may arise in such areas; it will be left to Departments or Divisions to resolve such matters when necessary.
- All PI's sharing the space will be expected to uphold all Radiation Safety requirements outlined in this manual.

4.2.4.1.3 Storage in Hallways and Corridors

Storage of radioactive materials in hallways, corridors, and other public areas is strongly discouraged because only small amounts of radioactive material can legally be stored in such areas, due to the fact that these public areas are not and cannot



be posted as “Caution: Radioactive Materials” areas, security of materials in such locations is of greater concern than in laboratories, and storing radioactive materials in such areas increases the risk of contamination in public areas.

Radioactive materials stored in hallways, corridors, and other public areas must meet the following criteria:

- Storage must be in a strong, securely-locked container that cannot be removed by an individual without mechanical assistance (e.g., a freezer, refrigerator, heavy steel box),
- The total quantity stored must not exceed the amounts specified in Appendix II and
- Any storage unit containing more than one tenth (1/10) of the amounts specified in Appendix II must bear the “Caution: Radioactive Materials” label on the exterior surface of the unit in a prominent location.

Storage in a hallway, corridor, or other public area is subject to the explicit approval of the CIR. Investigators who have a particular storage problem because they do not have the space or other necessities inside their laboratories to meet the above requirements may need to store their materials in another nearby PI’s laboratory.

4.2.4.2 Security of Radioactive Materials

The Colorado Rules and Regulations Pertaining to Radiation Control require that areas where radioactive materials are used must be controlled as:

- “Restricted Areas,” where “Restricted Area” means “an area to which access is limited by the licensee or registrant for the purpose of protecting individuals against undue risk from exposure to sources of radiation” (6 CCR 1007-1, 1.2.2), or
- “Unrestricted areas,” whereby “The licensee shall control and maintain constant surveillance of licensed or registered radioactive material that is in an unrestricted area and that is not in storage or in a patient.” (6 CCR 1007-1, 4.26)
- Areas where radioactive materials are in storage must be controlled such that “The licensee shall secure from unauthorized removal or access licensed or registered sources of radiation that are stored in unrestricted areas.” (6 CCR 1007-1, 4.25)



Because it is generally not practical for institutions like CU Denver | Anschutz to restrict access to laboratories, university laboratory areas that are authorized as locations of use for RAM must be controlled as unrestricted areas, and meet the applicable security requirements noted above.

4.2.4.2.1 Types of Areas

Areas where radioactive materials are **USED** must either be:

- locked to prevent access to members of the public (including untrained workers), or
- under constant surveillance by trained radiation workers who will protect others from the associated hazards.

Areas where radioactive materials (including waste containers) are **STORED but are never opened or used** must:

- Be locked, or
- Be under constant surveillance by trained radiation workers who will prevent unauthorized “removal of or access to” the stored materials, or
- Have those materials stored in strong, locked, immovable containers that will prevent unauthorized “removal of or access to” the stored materials.

The following points should receive careful consideration from Principal Investigators authorized for radioactive materials:

- Security improvements for campus buildings, including access control and “ID badges” do not lessen the need for security of individual laboratory areas.
- The operational criterion used by inspectors from the CDPHE is as follows: if an inspector can at any time gain access to a radioactive materials laboratory and discover radioactive materials in any form, without being confronted and asked for identification, etc., then a violation has occurred.
- For waste, Radiation Safety requires that all temporary waste receptacles be either secured or emptied into the main waste container before the area is left unoccupied by the radiation workers.
- When stock or working materials must be present in reaction mixtures or where ongoing experimentation cannot be secured or constantly



monitored due to logistical constraints Radiation Safety requires that these materials be the minimum activity that each experiment requires and that these items are only left unattended in a properly labeled area for the minimum time required for the experiment to be completed.

- **Any person who is not a fully trained and certified radiation worker is, by definition, a member of the public.** Areas where radioactive materials are used must have adequate supervision by trained and qualified radiation workers to prevent inadvertent exposures to such persons.

Principal Investigators' laboratories are subject to unannounced spot checks of security by Radiation Safety staff, the results of which are reported to the CIR.

4.2.5 Laboratory/Personnel Surveys and Exposure Control

4.2.5.1 Laboratory and Personnel Surveys

4.2.5.1.1 Frequency of Surveys

Survey frequency requirements are based on the hazard classification of the PI's authorization and include all types of surveys required by an authorization.

- Surveys are not required to be performed during periods when radioactive materials are not being used if a survey was performed after the last use of radioactive materials.
- Copies of the latest contamination surveys are examined by Radiation Safety during waste pickups. These surveys must be current (within the last day, week, or month) depending on the hazard class.
- During periods of continuous or frequent use surveys must be performed:

Hazard Classification	Frequency of Surveys
Low	Within 1 Month of Use
Medium	Within 1 Week of Use
High	Within 1 Day of Use



4.2.5.1.2 Types of Surveys

Both portable instrument surveys and swipe surveys must be performed, to determine if there is contamination and/or removable contamination on surfaces, equipment, and personnel.

- If H^3 is the only radionuclide in use, then only swipe surveys are required.

Swipe Surveys

- All RAM Authorizations require swipe surveys of their authorized area according to the frequencies above with an approved Liquid Scintillation Counter (LSC) or Auto-Gamma Counter to determine if there is removable contamination.
- A map of the survey area should be established and contain all locations that could be potentially contaminated throughout an experiment.
- A background swipe should be included on all surveys.
- Any results greater than 2x the background swipe should be noted, decontaminated, and re-swiped.
 - Report any contamination on floors or personnel immediately to Radiation Safety
 - Contact Radiation Safety for any contamination that cannot be controlled
- All records and results, including any decontamination efforts, should be maintained and readily available for review by Radiation Safety staff.

Portable Instrument Surveys

- Portable instrument surveys are required in addition to the swipe surveys and should be performed both BEFORE AND AFTER use of radioactive materials. Portable instruments should only be used in accordance with University training and laboratory authorizations for the use of radioactive materials.
 - The only exception is H^3 , portable instruments do not have the capability to detect H^3 .



- Radiation Safety will provide a form for recording the results of portable instrument surveys.
- Survey locations that are greater than 2x the background reading should be recorded, and decontamination efforts should be done.
- The appropriate type of instrument should be used:
 - For beta emitters, a thin end window or pancake GM probe should be used.
 - For gamma emitters, and Low Energy Gamma (LEG) probe should be used.
- Radiation Safety can provide portable instruments, if needed, and will calibrate all portable instruments annually. Prior to the purchase of new instruments, the Principal Investigator should verify with Radiation Safety that the proposed instrument is appropriate for use.

Decontamination Efforts

- Principal Investigators must ensure that any area indicating contamination (> 2x the background reading of portable instrument or swipe survey) is properly decontaminated.
- Any contaminated area must be resurveyed by both the portable instrument and swipe survey after decontamination is attempted.
 - If any area indicates persistent contamination from either type of survey, despite repeated efforts at decontamination contact Radiation Safety for assistance.⁷
- Records of both portable and swipe surveys for before, during, and after decontamination efforts must be annotated and retained with the PI's survey records.

4.2.5.1.3 Areas to be Surveyed

Each room in which radioactive materials are used must be surveyed. All potentially contaminated surfaces should be included such as:

- fume hoods and benchtop areas where radioactive materials are manipulated,
- floors and sinks near fume hoods and benchtop areas where radioactive materials are manipulated,
- exterior and interior surfaces of centrifuges, incubators, ovens, water baths, gel dryers, refrigerators, freezers, and other laboratory appliances in which radioactive materials are used or stored,



- exterior surfaces of radioactive waste containers, and
- light switches, doorknobs, and other high touch areas near the area where radioactive materials are used.

4.2.5.1.4 Decommissioning of Areas for Non-RAM Use

Radiation Safety must be notified whenever any particular authorized Principal Investigator will no longer use any particular area for radioactive materials, regardless whether:

- the space is being transferred to another authorized Principal Investigator, or
- other Principal Investigators previously authorized for common use of the area remain authorized and responsible, or
- The area is being returned to general use, such that radioactive materials will no longer be used in the space.

Upon such notification, Radiation Safety will review the contamination surveys of the appropriate authorized Principal Investigator(s) and may elect to perform additional confirmatory surveys for contamination. If the space is being returned to general use, EHS will verify that all radioactive materials, including waste, have been removed.

In addition to situations involving a change in the responsible Principal Investigator, areas authorized for radioactive materials always require a Green Tag for certain types of services performed by workers from outside the laboratory. A Green Tag from EHS is required for:

- renovation (painting, etc.),
- various other maintenance and repair services from the Facilities Department that require contact with laboratory surfaces such as laboratory benches, casework, sinks, and fume hoods,
- cleaning of laboratory benches, casework, sinks, and fume hoods; and
- other non-routine services provided by cleaning services.

Environmental Health and Safety should be contacted for guidance in specific cases.

4.2.5.2 Exposure Control



Persons who are not trained and monitored as radiation workers are by definition members of the general public for radiation protection purposes.

Because it is not feasible to control access to laboratories and nearby areas to exclude such persons, the radiation dose limits prescribed for the general public must be generally observed throughout CU Denver | Anschutz facilities. This means that:

- **Overall limiting dose guideline:** sources of penetrating radiations must be controlled so that any person who is not a trained and monitored radiation worker could not receive more than 100 mrems (1 mSv) in a calendar year;
- **Dose guideline for short time periods:** No source of radiation must ever create a condition where a dose rate exceeding two mrems (20 μ Sv) in any one hour could ever be received in any area accessible to any person who is not a trained and monitored radiation worker.

4.2.5.2.1 Shielding

Appropriate shielding requirements, if any, will be dictated by the CIR in the PI's authorization.

- It is the PI's responsibility to ensure the appropriate shielding is used and maintained.
 - Radiation Safety has a limited supply of shielding materials that are available upon request at no charge.

4.2.5.2.2 Eye Protection

Eye protection that suffices for general safety purposes will also provide considerable protection against high-energy betas and must always be worn when handling radioactive materials of any kind.

4.2.5.2.3 Personnel Monitoring Devices

A personal dosimeter for external whole-body exposure to penetrating radiations is required for:

- Adults likely to receive, in 1 year from sources external to the body, a dose more than 10 percent of the annual dose limits,



- Any minor for whom a permission form is required.
- Any other person designated by the CIR.

A finger ring badge is required for:

- Any person who will directly handle material containing more than 1 mCi (37 Mbq) of beta-emitting radionuclides with a maximum energy above 500 keV, and,
- Any person who will directly handle material containing more than 5 mCi (185 MBq) of any radionuclide that emits gamma rays and/or x-rays, unless specifically exempted by the RSO.

Any person who is issued a personal dosimeter for work at CU Denver | Anschutz shall wear that badge or device **ONLY** while working under the university's radioactive materials license.

- Work at University of Colorado Hospital, Veterans Administration Medical Center, or any other institution should be monitored by that institution.
- Any person who is being monitored by both the university and another employer or institution must notify the CU Denver | Anschutz RSO so that information may be exchanged to control the individual's total radiation dose.

Radiation Safety may impose additional requirements on the issuance, wearing, and exchange of personal monitoring devices, subject to the approval of the CIR.

4.2.5.2.4 Housing of Animals Containing Radioactive Materials

The dose guidelines above also pertain to animals containing radioactive materials. All precautions or requirements, if any, will be dictated by the CIR in the PI's authorization.

- Any change in procedure, including a change in the location of the animals' housing, must be approved by the CIR.

4.2.6 Radiological Hygiene



All Principal Investigators are expected to require the practice of good hygiene in all operations involving radioactive materials. The ways that radioactive materials are used in biomedical research, and the types of materials used, are such that the greatest hazard of receiving a significant radiation dose is typically the one associated with internal dose from self-contamination due to inadequate hygienic practices.

The only way to detect internal contamination is by bioassay measurements, and the usage levels above which bioassay is required for personnel, as stipulated by the CIR, are predicated on the assumption that good hygienic practices are being followed.

Finally, poor hygiene can result in the spread of contamination to public areas and/or individuals who are not radiation workers, and contamination may be transported to homes and other uncontrolled environments by contaminated individuals if proper practices are not observed. The U.S. Nuclear Regulatory Commission (USNRC), Inspection and Enforcement Division, publishes bulletins on a regular basis, detailing the extremely aggressive enforcement actions taken by the NRC in response to such transport of contamination into the larger outside community, providing a palpable indication of the regulatory agencies' particular sensitivity to this issue, which is capable of arousing great public sentiment.

4.2.6.1 Control of Contamination

Almost all contamination problems arise from one or both of the following:

- Spills of liquid, however small, which occur mostly during operations transferring the liquid from one vessel to another, or
- Transfer by touching with the hands.

Persons working with radioactive materials should have an understanding of contamination surveys as they pertain to their lab and experiment, and should appreciate the need for proper surveys of themselves and laboratory surfaces before and after radioactive materials are used.

4.2.6.2 Protective Apparel

Persons handling radioactive materials **MUST**, without exception wear:

- Eye protection,



- Gloves,
- Lab coats,
- Closed toe shoes,
- and long trousers.

Eye protection is especially crucial and is required for all laboratory operations involving any type of eye hazard, not just radioactive materials, as stipulated in EHS Policies.

In some cases, additional protective apparel, beyond the items noted above, may be advisable. The RSO should be consulted when questions arise.

4.2.6.3 Safe Practices

The safe practices discussed in previous sections should be followed as applicable. Most importantly, two egregiously unsafe practices must be avoided: mouth pipetting, and eating and drinking in areas where radioactive materials are used.

4.2.6.4 Control of Equipment Used with Radioactive Materials

No piece of equipment used with radioactive materials should leave the laboratory for any reason, including maintenance, repair, calibration, moving of the laboratory, or sale/transfer to another user, until it has been properly tested for contamination and there is a documented survey performed by PI or laboratory personnel. In the case of larger items of equipment, EHS may choose to perform confirmatory surveys before releasing the equipment through the Greentag process.

4.2.7 Radioactive Waste Storage and Disposal

4.2.7.1 Radioactive Waste Definitions and Types

Radioactive Waste is defined as any waste material that is known or suspected to contain any licensed radioactive material in any quantity whatsoever.

- It must be emphasized that such waste must be treated as radioactive waste until determined otherwise.



- If there is any suspicion that an item of waste is contaminated with licensed radioactive material, it is the responsibility of the authorized investigator to use appropriate and sufficiently sensitive assay methods to determine that there is no contamination before treating it as non-radioactive.

Infectious Radioactive Wastes is defined as waste containing pathogens or biologically active material which because of its type, concentration and quantity could present a potential hazard to human health when improperly handled, stored, processed, transported or disposed of.

- Wastes presumed to be infectious medical waste include blood and body fluids, potentially infectious waste, pathological waste, sharps, in addition to the property of being radioactive.

4.2.7.2 Security of Radioactive Waste

Licensed radioactive materials including all radioactive waste must never be left unsecured and unattended in any location, for any reason, at any time.

4.2.7.3 Segregation, Classification, and Packaging of radioactive Waste

Radioactive waste occurs in several forms in a biomedical research setting. Different waste forms must be properly segregated, classified, packaged, and **never mixed**. Mixing waste types may make waste disposal very expensive and perhaps impossible.

- **Dry Solids (DRY):** Includes paper, plastic, glass, and metals other than lead or the other excluded metals as listed below and which is radioactive. Laboratories must segregate radionuclides in dry solids with half-lives less than 90 days from those with longer half-lives unless approved by Radiation Safety.
 - Radionuclides with half-lives less than 90 days include ^{32}P , ^{33}P , ^{51}Cr , ^{125}I , and ^{35}S .
 - Stored in yellow containers provided by Radiation Safety and in RAM labeled trash bags.
 - Other containers may be used for waste storage upon Radiation Safety approval



Dry lab trash must not contain:

- Freestanding liquids, wet absorbent materials, or wet gels. Containers, regardless of size, must have been emptied of liquids to the maximum practical extent. Wet absorbent materials and gels must be dried in a certified fume hood unless potentially volatile radioactive materials are involved, in which case EHS should be contacted at x4-0345 for advice.
 - Organic solvents must not be present in any amount whatsoever.
 - Regulated metals such as arsenic, barium, cadmium, chromium, lead, mercury, selenium or silver.
 - Empty scintillation vials.
 - Biological materials or infectious materials (see below)
 - Sharps, such as blades or needles. Glass with sharp edges may be included if it has not been in contact with human blood or serum or other infectious material, but must be packaged in a rigid plastic container to avoid injury to EHS personnel.
 - For questionable items, it is easy to specify a common-sense rule of thumb: if the item contains material that, if it were left at room temperature for an extended time, would putrefy to an extent that would be detectable upon opening and inspection, it does not belong in dry solids.
- **Aqueous (AQU):** Consists of radioactive solutions involving water as the only solvent. Such liquids must not contain any organic solvents (including alcohols) or infectious materials.
 - Stored in jerry cans provided by Radiation Safety
 - **Organic Liquids (ORG):** Often called “organic” or “mixed” waste; includes all wastes containing radioactive material and solvent whose chemical attributes alone would classify them as a “hazardous waste” under the Colorado Hazardous Waste Regulations, and Federal regulations.
 - Radiation Safety must be consulted prior to any new type of RAM contaminated organic liquid is generated (contact EHS at RAD.WASTE@cuanschutz.edu)
 - Stored in glass jugs appropriate for the chemical hazard
 - **Non-Hazardous Scintillation Vials (NHV):** Scintillation vials containing non-hazardous cocktails and no hazardous chemicals (Refer to Appendix _ for Hazardous and Non-Hazardous Scintillation Cocktails).



- **Hazardous Scintillation Vials (HZV):** Includes scintillation vials that are regulated by RCRA and is defined as any of the characteristics identified in 40 CFR Subpart C 261.20 (ignitability, corrosivity, reactivity, and toxicity), 261.31 (hazardous wastes from non-specific sources), and 261.33 (discarded commercial chemical products, off-specification species, container residues, and spill residues thereof).
- **Stock Vials (STK):** Unused Stock in stock vials applies to vials containing unused radioactive materials as supplied by vendors. Such waste should remain in the original vial and placed in its original pig and/or sturdy outer container, with appropriate shielding if indicated, for pick-up by Radiation Safety.
 - Unused stock materials should never be placed into, or mixed with, scintillation vial wastes or added to aqueous waste.
- **Animal Tissue (ANI):** Animal carcasses or tissue is a classification to any substantial amount of tissue, including blood contaminated with radioactive material. Such waste should be kept frozen in minimal and easily removed packaging, e.g., multiple small carcasses together in a plastic bag, with any liquid blood fully absorbed in absorbent or in disposable bottles.
 - Researchers generating such wastes are strongly encouraged to contact Radiation Safety at RAD.WASTE@cuanschutz.edu to make prior arrangements for packaging these wastes.
- **Non-Carcass Biological Waste (BIO):** Non-Carcass Biological Waste is a classification that includes all radioactive waste materials that were ever previously classifiable as infectious before they were disinfected. This includes the following:
 - Human blood,
 - Human serum,
 - Other infectious human bodily fluids, or
 - Human pathogens,
 - Human cell culture lines (considered infectious unless they have been specifically demonstrated to be free of infectious potential and



documentation is provided) as well as any other cell culture line known to be infectious.

- Animal bedding,
- Biologically contaminated sharps in approved sharp containers, and
- Plastic tubing, culture vessels of various types, and all other liquids and solid material contaminated with small amounts of biological materials.
- As long as disinfected, stored the same way as Dry Lab waste in a separate container.

All infectious radioactive wastes must be disinfected by appropriate methods and classified as biological non-carcass wastes. Specific guidance is available from the Biosafety Officer at x4-0235.

- **Patient (PAT):** This waste form is to keep a record of all radioactive material that are administered to patients and that the material decays out through the patient's body.
- **Sewer Disposal (SEW):** Sewer disposal (H-3 ONLY) Pursuant to the ruling of the Committee on Ionizing Radiation, certain aqueous solutions of ^3H may be disposed of into the sink a designated sink by laboratory personnel. Such disposals must conform to the following stipulations:
 - **The material disposed *must contain only ^3H and total radioactivity must be diluted to a concentration less than 0.01 uCi/ml (= 10 microCi/liter) before being poured into the sink.***
 - It is not acceptable to dump radioactive material in small volumes and simply allow the water to run - the dilution requirement is designed to preclude having substantial mCi amounts of materials in the plumbing at any one time, in case a blockage should occur.
 - The radioactive material must be in a form that is readily soluble or dispersible in water and must not possess any chemically or biologically hazardous attributes that would preclude its disposal by sewage under other university guidelines, Denver Metropolitan Wastewater Regulations, or the Colorado Hazardous Waste Regulations.
 - Appropriate entries must be made on all associated *User's Radioactive Material Accounting Sheets*. Waste tickets for amounts of radioactivity that were disposed by sanitary sewer for ^3H will be



- emailed directly to Radiation Safety at RAD.WASTE@cuanschutz.edu or presented at the time of waste pickup.
- The **sink must be labeled** as a radioactive materials disposal sink, using standard Radioactive Materials caution signs, and a log showing sink disposal history must be placed in a readily accessible location near the sink. *Radioactive Materials Sink Disposal Log* forms are available from Radiation Safety.
 - The sink must be swipe tested for contamination after each disposal and kept free of removable contamination on the accessible surfaces.
 - Sink disposal of other isotopes apart from ^3H must get an approval from the RSO prior to any disposal.
 - Materials disposed under these provisions must be properly assayed and records of those assays must be maintained by the PI.
- **Bactec Vials (BAC):** Bactec vials constitute a unique waste form that derives from a procedure used in clinical microbiology. They consist of ^{14}C -labeled substrates in culture media, contained in small (~35 ml) glass vials, ranging from 2 to 4 μCi per vial. Contact Radiation Safety for instructions on how to handle this waste.
 - **Uranium (Uranyl Acetate/Nitrate):** Natural or depleted uranium is not controlled in the same manner as most radioactive materials, as it is regarded as “source material” that is mined directly from the earth. Materials such as uranyl acetate and uranyl nitrate can be purchased without going through Radiation Safety. However, these materials do become regulated as RAM once it is considered waste. Contact Radiation Safety to properly dispose of these materials.

4.2.7.4 RADIOACTIVE WASTE PICKUP AND DISPOSAL PROGRAM

Radiation Safety picks up radioactive waste at the request of laboratory personnel.

ONLY RADIATION SAFETY PERSONNEL ARE AUTHORIZED TO TRANSPORT RADIOACTIVE MATERIALS AND RADIOACTIVE WASTES.

To make a request for radioactive waste pickup, submit a waste pickup request form, available on our website:

<https://research.cuanschutz.edu/ehs/home/divisions/radiation-safety/radioactive-waste-disposal>



When filling out RAM Waste Pick-up Request form, please be prepared to specify:

- PI's name(s),
- Requestors name
- Requestors' Phone #
- Building & Room # where the waste is located,
- Classification of waste type
- Associated total activity (mCi) for each waste type, and
- Size and # of waste containers for pickup.

Pre-coded waste tickets should be completed for each waste form prior to scheduled pickup. Radiation Safety will not give credit for disposal after the fact.

Waste Pick-up Request for Mixed Chemical Waste

Mixed waste pickup requests must be made on a "Radioactive Mixed Chemical Waste Disposal Form" found electronically in the Forms section of the EHS website.

- This form is not required for liquid scintillation vials that are classifiable as hazardous.

When filling out "Radioactive Mixed Chemical Waste Disposal Form", please be prepared to specify:

- PI's name(s),
- Requestors name
- Requestors' Phone #
- Building & Room # where the waste is located, and
- Chemical Name (No Abbreviations)
- Isotope(s)
- Activity (mCi)
- Percent Content (%) of waste mixture
- Total Volume (liters, grams)
- Physical State (S, L, G)
- Contaminates Present (Y/N)
 - Contaminants Present: Indicate if the waste contains any infectious agents (e.g. human serum), heavy metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, uranium), PCBs, dioxin, asbestos, water reactive drying agents (e.g. sodium hydride), or other significant contaminants.



- If (Yes) attach a note to the container listing the name and concentration of contaminant(s).

Section V: Emergencies

EMERGENCY TELEPHONE NUMBERS

Where to call for:	Weekdays 8 a.m. – 5 p.m.	After Hours, Weekends, & Holidays
CU Police – Anschutz Campus	911(from campus phone) 303-724-4444 (any phone)	911 (from campus phone) 303-724-4444 (any phone)
Auraria Police – CU Denver Campus	911 (AHEC campus phone) 303-556-5000 (any phone)	911 (AHEC campus phone) 303-556-5000 (any phone)
Fire	911	911
Medical Emergencies	911	911
Hazardous Materials Spills (Chem/Bio/Rad)	303-724-0345	911
Research Safety & Industrial Hygiene	303-724-0345	911
Other	303-724-0345	911
Colorado Department of Public Health and Environment	(303) 692-3320 (303) 692-3300 <i>Toll Free (888) 569-1831</i>	(303) 877-9757



RADIATION SAFETY ROUTINE TELEPHONE NUMBERS

Where to call for:	Weekdays 8 a.m. – 5 p.m.	After Hours, Weekends, & Holidays
Radiation Safety Officer (RSO)	303-724-0128	911 (from campus phone) 303-724-4444 (any phone)
Alternate RSO	303-724-0256	911 (from campus phone) 303-724-4444 (any phone)
Radioactive Waste Pickups	303-724-0109 <i>(or On Line)</i>	*****
Radioactive Materials Inventory and Paperwork	303-724-0109 or 303-724-0256	*****
General Questions	303-724-0345	911
Personal Dosimeters	303-724-0345	*****



Incidents Requiring Reporting to Environmental Health and Safety

Any person involved in any of the following types of incidents must ensure that Environmental Health and Safety is informed immediately by telephone:

- Any incident involving possible contamination of an individual's person (any part of the body, including contamination of clothing that may transfer to the body),
- Any incident involving disappearance or loss of control of radioactive material, including improper disposal,
- Any incident involving known or suspected contamination of floors, and
- Any incident involving radioactive contamination that cannot be immediately and completely contained and controlled.

Contact telephone numbers are listed on the first page of this manual. When calling Environmental Health and Safety, you will be asked:

Your name,

Names of potentially affected individuals,

Location of the incident,

Type and amount of radioactive material involved and,

A description of the incident



Emergency Procedure for Radioactive Spills

If the spill involves

- a portion of the floor that cannot be quickly and completely contained and cordoned off, or
- volatile forms of radioactive material (e.g., radioactive iodine in sodium iodide solution, tritiated water in millicurie (mCi)-or-greater quantities),

YOU MUST EVACUATE the laboratory and close the doors **BUT DO NOT** allow any persons who were in the laboratory to leave the area.

- Address any contamination of persons according to the Emergency Response Procedure for Personal Contamination (*found on the previous page of this manual*).
- Call Environmental Health and Safety (303-724-0345 or 911).
- All persons who were in the laboratory must remove any potentially contaminated footwear and place it in a secure area.

If the spill did not require evacuation of the laboratory by the above criteria, then you may begin decontamination operations:

- don your lab coat, gloves, and eye protection,
- cordon off an area that is certain to contain the spill so that no other person will enter,
- use disposable paper towels or pads to absorb any liquid and place into a radioactive waste liner, changing gloves frequently,
- decontaminate the spill with a detergent solution or a commercial preparation intended for radioactive decontamination, by soaking paper towels in the solution, wiping toward the center of the spill, and placing the towels into the radioactive waste liner,
- survey the area after each such effort to determine residual contamination levels, and attempt to remove all detectable contamination by continuing such efforts until no removable contamination appears on swipe samples.



Emergency Procedure for Personal Contamination

If the exposure involves a liquid containing chemicals that are caustic to the skin or a solution of radioactive iodine such as sodium iodide (NaI), flushing with water must begin IMMEDIATELY.

Use:

- a safety shower for large areas of the body,
- an eyewash for the eyes, or
- a laboratory water tap for small areas of the body.

Ask a nearby person to call Environmental Health and Safety (303-724-0345 or 911).

Place any contaminated clothing into a sealed plastic bag for later survey and disposition.

DO NOT use chemical or mechanical methods that may damage the skin, which will worsen the situation. Use only mild soap or detergent and warm water. Wash water may be disposed down the drain if it is not practical to contain it in the sink.

DO NOT leave the area until Environmental Health and Safety has addressed the situation.



Appendix I CDPHE ALI Limits

Isotope	CDPHE ALI (mCi)	Isotope	CDPHE ALI (mCi)
Au-198	1.000	I-131*	0.030
Ba-133	2.000	In-111	4.000
C-14	2.000	Lu-177*	2.000
C-11	400.000	Mn-54	2.000
Ca-45	2.000	P-32	0.600
Cd-109*	0.300	P-33	6.000
Cl-36	2.000	Pb-203	5.000
Co-60	0.500	Pd-109	2.000
Cr-51	40.000	Po-210	0.003
Cu-64	10.000	Re-186	2.000
F-18	50.000	S-35	6.000
Fe-55	9.000	Si-32*	2.000
Ga-67	7.000	Sr-90*	0.030
Ga-68	20.000	Tc-99m	80.000
Ge-68	5.000	Ti-204	2.000
H-3	80.000	Y-90*	0.400
Ho-166	0.900	Zn-65	0.400
I-125*	0.040	I-129	0.005

* Refer to CDPHE Part 4 Appendix 4B Table 4B1 for additional/specific information on ALIs values



Appendix II Table of Quantities for Labeling and Posting

Isotope	Amount (mCi)	Isotope	Amount (mCi)
Au-198	0.100	I-131	0.001
Ba-133	0.100	In-111	0.100
C-14	0.100	Lu-177	0.100
C-11	1.000	Mn-54	0.100
Ca-45	0.100	P-32	0.010
Cd-109	0.001	P-33	0.100
Cl-36	0.010	Pb-203	1.000
Co-60	0.001	Pd-109	0.100
Cr-51	1.000	Po-210	0.0001
Cu-64	1.000	Re-186	0.100
F-18	1.000	S-35	0.100
Fe-55	0.100	Si-32	0.001
Ga-67	1.000	Sr-90	0.0001
Ga-68	1.000	Tc-99m	1.000
Ge-68	0.010	Tl-204	0.100
H-3	1.000	Y-90	0.010
Ho-166	0.100	Zn-65	0.010
I-125	0.001	I-129	0.001