University of Colorado

Boulder and Colorado Springs campuses

RADIATION SAFETY HANDBOOK

(Guidelines and Policies of the Radiation Safety Program)

2019

University of Colorado
Department of Environmental Health & Safety
Radiation Safety Office
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Important Contact Information

Boulder Campus (UCB)

Radiation Safety Office (Campus Hours)	(303) 492-6523
Radiation Safety Office FAX:	(303) 492-1322
Radiation Safety Office e-mail:	radsafety@colorado.edu
EH&S Department	(303) 492-6025
EH&S Webpage	http://ehs.colorado.edu
EH&S BioRAFT portal	https://colorado.bioraft.com

Colorado Springs Campus (UCCS)

UCB Radiation Safety Office (Campus Hours)	(303) 492-6523
Public Safety	(719) 255-3111

Emergency Contact Information

Boulder Campus (UCB)

Radiation Safety Office (Campus Hours)	(303) 492-6523
EH&S Department (Campus Hours)	(303) 492-6025
UCB Police Dispatch (After Campus Hours)	911 or (303) 492-6666

Colorado Springs Campus (UCCS)

UCB Radiation Safety Office (Campus Hours)	(303) 492-6523
Public Safety (After Campus Hours)	(719) 255-3111
UCCS Police Department	9-911

Foreword

In 1969, the State of Colorado entered into a legislative agreement with the United States Nuclear Regulatory Commission (US NRC) to govern the safe use of radioactive materials – becoming one of 37 states referred to as "Agreement States." Under the agreement, the Colorado Department of Public Health and Environment (CDPHE) is responsible for developing and overseeing regulations pertaining to the use of radiation in Colorado. The regulations promulgated as part of the Colorado Rules and Regulations Pertaining to Radiation Control must be at least as restrictive as those established by the US NRC.

The State of Colorado, through CDPHE, has issued a Radioactive Materials License to the University of Colorado which authorizes the safe use of radioactive materials on the Boulder and Colorado Springs campuses. To facilitate the diversity of research at CU, this license is broad in scope and requires certain oversight within the University community. The License specifically requires that the University have a Radiation Safety Committee (RSC) and a Radiation Safety Officer (RSO). The RSC and RSO work together to ensure safety and regulatory compliance for individuals working with radioactive material or radiation; for the faculty, staff, and students of the University; and for members of the public.

Composed of members of the faculty and staff representing various departments and levels of experience with radiation, the RSC essentially serves as the on-site regulatory agency for the University. The Committee has been granted authority to establish policies and procedures, oversee the safe use of radiation on campus and provide enforcement sanctions or restrict the use of radiation if necessary. Other than the RSO, each member is appointed through University Administration. Efforts are made to maintain representation from each of the departments that actively use radioactive materials in research and/or academic work.

The RSO is an individual approved by the State of Colorado who has the knowledge, responsibility, and authority to apply appropriate radiation protection regulations. The RSO works closely with the RSC to review, approve and manage individual PI licenses authorizing specific uses of radiation.

As members of the CU Department of Environmental Health and Safety, the RSO and Radiation Safety staff provide daily management and support services for the safe use of radioactive materials and radiation. The Radiation Safety Office works closely with the RSC to ensure safety and regulatory compliance, while striving to promote successful research and academic efforts at the University of Colorado. Members of the RSC and the RSO may be contacted through the CU Radiation Safety Office.

Radiation Safety Goals:

- Ensure safety and compliance when using radioactive materials and radiation-producing machines in a high-quality teaching and research environment
- Assist CU researchers in complying with applicable Federal, State, local, and University requirements
- Assist in the prevention and/or minimization of radiation exposures
- Assist in the prevention of personal, laboratory, and environmental contamination

Charge from Chancellors

April 9, 2019

Brandon Boger, Director
Environmental Health and Safety
University of Colorado at Boulder
1000 Regent Drive, 413 UCB
Boulder, CO 80309-0413

Dear Mr. Boger:

Pursuant to Regent Policy 3.B.1 and as chief academic and administrative officers of the University of Colorado at Boulder and Colorado Springs, we have the responsibility to ensure research and instruction which use radioactive materials is accomplished in a safe and compliant manner. To that end, we hereby delegate to you, as well as the Radiation Safety Officer and Radiation Safety staff, authority to act as custodians for the purpose of enforcing the Laws and Policies of the Regents, applicable municipal ordinances, and State and Federal statutes specific to radiation safety. This authority to act shall include, but not be limited to:

1. Ensuring full compliance with the University's Radioactive Materials License issued by the State of Colorado through the Colorado Department of Public Health and Environment as well as any other applicable Federal, State, and local regulations;

2. Supporting the functions of the Radiation Safety Committee with representatives from the Boulder and Colorado Springs campuses;

3. Developing and issuing policies and procedures that clarify radiation safety issues and responsibilities at the Boulder and Colorado Springs campuses;

4. Acting in an advisory capacity to students, faculty, and staff in matters pertaining to radiation safety and compliance;

5. Serving as liaison between the University and Federal, State, and Local agencies in matters pertaining to radiation safety and compliance; and

6. Suspending activities and/or operations and closing areas where imminently dangerous conditions and/or non-compliance with regulatory requirements exist.

Approved by,

DocuSigned by:
Philip DiStefano
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Philip P. DiStefano, Chancellor
University of Colorado at Boulder

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University of Colorado at Colorado Springs

Purpose of the Radiation Safety Handbook

All personnel using radiation in University facilities should be familiar with the University guidelines and policies regarding the safe use of radiation. This handbook helps provide some of that information, along with the Radiation Safety Training available to campus radiation users. The CU Radiation Safety Office is also available as a resource for any questions which may arise.

A common acronym used in radiation safety is ALARA, which stands for As Low As Reasonably Achievable. The ALARA philosophy attempts to incorporate physical, social, and economic factors in reducing doses to individuals. The CU Radiation Safety Program tracks and evaluates efforts at keeping doses and exposures ALARA for both the University community and members of the public. It is the responsibility of each person who uses radiation in their work to enact safe practices which keep the dose to themselves and the people around them ALARA. This handbook also provides some concrete ideas for engaging with the ALARA philosophy.

Some of the easiest ways to protect yourself from radiation include: Time, Distance, and Shielding. Radiation dose can be minimized by taking advantage of the following simple methods:

1. Reduce the amount of time spent near the radioactive material/source
2. Increase the distance from the source
3. Use appropriate shielding whenever possible

Abbreviations Used in this Handbook

US NRC	United States Nuclear Regulatory Commission
CDPHE	Colorado Department of Public Health and Environment
RSC	CU Radiation Safety Committee
RSO	CU Radiation Safety Officer
ALARA	The philosophy of keeping radiation dose As Low As Reasonably Achievable
EH&S	Department of Environmental Health & Safety at the CU-Boulder campus
IBC	Institutional Biosafety Committee
IACUC	Institutional Animal Care and Use Committee
LSC	Liquid Scintillation Counter
Ci (mCi, etc)	Curie; Unit to measure radioactivity in a sample of material
Bq (MBq, etc)	Bequerel; SI unit to measure radioactive in a sample of material
mR/hr	Unit of radiation exposure used to describe ionization in air
cpm	Counts per minute; Unit of radiation measurement related to dpm (disintegrations per minute)
rem (mrem)	Radiation-equivalent Man; Unit to measure radiation dose in tissue
Sv (mSv, etc)	Sievert; SI unit to measure radiation dose in tissue

Radiation Fundamentals

Radioactivity is defined as the spontaneous emission of energy over time, generally in the form of particles or light waves, from an atom which is unstable due to an imbalance of neutrons and protons. Radiation may occur as particles (such as alpha particles, beta particles or neutrons) or photons (such as gamma rays or x-rays) emitted from an unstable atom as the result of radioactive decay. Each type of radiation emission has unique safety considerations and handling techniques. Not all forms of radiation produce the same biological effect when they interact with human tissue.

Isotopes are atoms which have the same number of protons and electrons but a different number of neutrons. Therefore, isotopes have different physical properties. Some elements have many isotopes but not all are unstable enough to be radioactive. Isotopes which emit radiation are referred to as radioisotopes.

Each radioisotope emits radioactive energy at a specific rate, which can be measured. The amount of time it takes for half of the atoms in a radioactive sample to emit energy (or decay) is referred to as the half-life of the radioisotope. Half-life becomes very important when choosing a radioisotope to use in a research experiment. Ideally, a researcher will want the radiation to be detectable from a sample long enough to be detected during the experiment, but not so long after that the waste materials are difficult to dispose.

Background Radiation and Risk

Radiation is part of everyday life. There are many sources of natural background radiation, both external and internal. The average radiation dose from exposure to natural and man-made background radiation in the United States is approximately 3.6 mSv (360 mrem) per year. Living at the higher altitude in Boulder, Denver, or Colorado Springs increases the average background dose to approximately 5 – 6 mSv (500-600 mrem) per year. The increase is due to a higher contribution from cosmic radiation at higher altitudes and terrestrial radiation from naturally-occurring radioisotopes in the rocks and soil of the surrounding mountains. The greatest contributor to background radiation dose is from radon gas in the air around us. We even have some naturally-occurring isotopes of common elements within our own bodies. If the body needs a certain element as a building block, it doesn't distinguish between stable or radioactive forms of that element.

The main biological effect we are concerned with when exposed to radiation for any reason is the development of cancer. There is no way to measure how much radiation it takes to cause cancer, because of the many other factors involved in the development of malignancies. For this reason, we should implement ALARA principles and safe work practices to reduce risk as much as possible. The amount of radiation used in most research at CU is much less than what one is exposed to from background sources and much, much less than medical sources of radiation exposure. The risk that using radiation in your work will end up shortening your lifespan is significantly lower than many other everyday activities in which we engage without a second thought – such as driving a car or not getting enough sleep.

Common Units

There are many words used to describe radioactivity, such as: activity, dose, dose equivalent, and exposure. Each of these terms comes with its own units, in both conventional and System International (SI). At the University of Colorado, subdivisions of conventional units such as millicuries (mCi) and millirem (mrem) are used along with divisions of SI units such as megabecquerel (MBq) and millisievert (mSv). More information about these terms and units is available in the Radiation Safety Training modules. Some common units are introduced here for ease in communicating throughout this handbook.

Systeme International (SI) Units

Activity

1 Bequerel (Bq) = 1 disintegration / second

1 Bq = 2.7027 x 10^{-11} Curies

1 kBq = 1,000 Bq = 2.7 x 10^{-8} Ci = 2.7 x 10^{-5} mCi

1 MBq = 1000 kBq = 1,000,000 Bq

Dose

1 Gray (Gy) = 1 Joules/kilogram (J/kg) = 100 Rad

1 Gy = 100 centiGray (cGy)

1 cGy = 1 Rad

Dose Equivalent

1 Sievert (Sv) = 1 J / kg = 100 rem

1 mSv = 0.1 rem = 100 mrem

Conventional Units

Activity

1 Curie (Ci) = 3.7 x 10^{10} disintegrations / second

1 Ci = 1000 mCi

1 mCi = 1000 μCi

1 mCi = 37,000 kBq = 37 MBq

Dose

1 Rad = 100 ergs / gram = 0.01 J / kg

1 Rad = 0.01 Gy

Dose Equivalent

1 radiation equivalent man (rem) = 1000 mrem

1 rem = 0.01 Sv

1 mrem = 0.01 mSv

Laboratory Licensing

At the University of Colorado, qualified full-time faculty or staff members may be issued an authorization (commonly referred to as a "license") to use radiation from the Radiation Safety Committee (RSC). This authorization must be obtained prior to working with radiation on campus and must be kept current if research needs change. Applications for a new license, license amendment, license renewal, or license termination go through the CU Radiation Safety Office for review and approval by the RSC.

New Licenses

New licenses are reviewed only at quarterly meetings of the RSC. Applicants should allow plenty of time for processing of applications. The CU Radiation Safety Office may have questions and will need to schedule a visit to the proposed use facility before the license application can be reviewed by the RSC. Certain information is required for the RSC to be able to review and approve applications to use radiation, which includes: proposed licensee contact information, laboratory contact information, radionuclide information and limits, proposed radiation use areas, experimental procedures, equipment to be used, waste information, and past training and experience of the proposed licensee.

A laboratory visit will be scheduled for applicants to review facility needs, equipment, signs and labels, proposed use areas, waste storage areas, and address any other questions from the proposed licensee. At some point during the application process, the CU Radiation Safety Office will create a laboratory instance for the radiation authorization in BioRAFT.

Once approved by the RSC, the licensee will be asked to sign formal license documents, usually through DocuSign. Part of the signature process includes a certification from the new licensee that they will be responsible for the safe and compliant use of all radiation under their authorization. Radiation licenses are generally approved for three years.

License Application

Contact Information

Unless otherwise specified, the questions on the application should be answered from the perspective of the person wishing to obtain authorization to use radiation from the RSC (the PI or Licensee). Only faculty members or full-time/permanent researchers may be authorized as a radiation licensee. Licensee and laboratory contact information includes: office building and room, office telephone, emergency (home or cell) telephone number, email and campus mail information.

Each licensee should name another contact in case they are unavailable during an emergency impacting the radiation use area. For small laboratories, this contact may be an "Alternate Safety Contact" who is aware of the work being performed in the lab, even if they are not an active radiation user. Larger laboratories frequently prefer to name a "Radiation Safety Laboratory Contact," an active radiation user who can act as a liaison between laboratory personnel and the CU Radiation Safety Office.

Depending on the size of lab and type of radiation use, the licensee may wish to name a “Dosimetry Contact” to be in charge of exchange of laboratory dosimeters and/or a “Survey Contact” to make sure appropriate contamination surveys are completed and reported as required.

Radiation Use

Different types of proposed radiation work may require different applications or parts of the application to be completed. Applications may generally be split up between unsealed radioisotope use, sealed radiation source use, and x-ray machine use.

For unsealed radioisotope use, necessary radionuclide information includes the name and atomic number of the radionuclide(s), amount of activity required for each experiment (experimental limit), total amount of radiation allowed in the laboratory at one time - in stock vials, aliquots and waste - as well as allow for an extra order of isotope if needed (possession limit). Physical and chemical form of the radionuclide(s) requested should also be included. These may be listed in broad categories, such as “nucleic acids” vs CTP, dGTP, etc.

For sealed source use, necessary radionuclide information includes the name and atomic number of the radionuclide(s), the experimental limit would be the amount of activity in each source, and the possession limit would be the total amount of each radionuclide in the lab (for instance, a lab wishing to order two 0.5 mCi ^{60}Co sources would list the experimental limit as 0.5 mCi and the possession limit as 1 mCi for ^{60}Co). The type of source will be listed under physical and chemical form, such as plastic rod source or ECD. If source ID numbers and manufacturer are known, it can be helpful to add in this information.

For x-ray machine use, as much information as is known about the machine should be listed on the application. The power and use time are particularly important for the CU Radiation Safety Office to determine adequate shielding and dosimetry needs.

Location of use should include the building, room number(s) and telephone numbers (if available) for all rooms in which radiation will be used or stored under the authorization of the licensee. If the PI does not have a LSC of their own and will be using one in another lab, the room number for the LSC which will be used also needs to be listed as a licensed radiation use area for the applicant.

Experimental Protocol

New license applications and some license amendments need to include a brief description of the proposed experimental procedures which describe the experiment and operating procedures to be used with the requested radiation. This section should include a statement indicating whether or not hazardous, biohazardous materials or animals will be used in conjunction with the requested radiation. Biohazardous material or animal use also require approval through the campus IBC or IACUC Committees.

Operating procedures should include information to limit the spread of contamination, frequency of surveys, analysis methods such as LSCs, proposed field locations and any special logistics required to compete the experiment.

Facilities and Equipment

New license applications and some amendments should include information regarding items of equipment which will be used with radiation – particularly if there is a chance the equipment may become contaminated. Not all equipment items listed on the application will apply. The application asks for information regarding certain types of common equipment and includes type, make, model, serial number and location. If equipment requires internal radiation or calibration sources (such as many LSCs), information on these sources should be included: radionuclide, activity, physical and chemical form, manufacturer and assay dates of the source(s).

Laboratories are expected to provide radiation detection equipment, including survey meters, as well as appropriate shielding for the radioisotope(s) in use. The CU Radiation Safety Office is available to offer suggestions on the best types of survey meters and shielding. In addition, meter and LSC calibration is available through the CU Radiation Safety Office at no additional charge for campus radiation users. If an instrument requires a more in-depth calibration or needs repair beyond basic fixes, the laboratory may be asked to cover these expenses through the instrument manufacturer.

Radioactive Waste

Waste information should be broken into type of waste (solid, liquid, scintillation vials, sharps), expected volume, approximate percentage of the total waste represented in each type, and chemical constituents. All laboratories using unsealed radioactive material are required to perform contamination surveys, and therefore, will generate scintillation vial waste. Laboratories are required to use biodegradable scintillation cocktails unless special arrangements are made through the CU Radiation Safety Office. Waste containers appropriate for radioactive waste collection are provided by and available from the CU Radiation Safety Office. Laboratories are asked to segregate radioactive waste according to the half-life of the radionuclide to facilitate disposal and waste minimization. Waste is picked up, processed and properly disposed by the Radiation Safety Office for all campus radiation uses.

Chemical constituents should be listed completely and without abbreviations, such that the total contents listed equal 100%. For solids, a general list of waste included is acceptable, such as “paper, plastic, plastic pipette tips, gloves – all equal to 100%.” However, liquid waste needs to be much more specific to allow for proper disposal. Laboratories may be asked to separate a waste stream containing a hazardous component from other waste streams to minimize the production of mixed radioactive-hazardous waste, which can be costly and environmentally damaging to dispose. It is a good idea to contact the CU Radiation Safety Office before making any changes to the chemical constituents in an approved waste stream so that hazardous waste production is minimized.

Protocols which produce mixed radioactive and biohazardous waste should include a step in the experimental process in which the biohazard is rendered non-infectious. This is generally accomplished by the addition of a certain percentage of bleach solution. Note that NO radioactive materials may be autoclaved.

When considering available facilities for proposed radiation use, please keep in mind that waste areas in laboratories should be kept separate from regular (non-radioactive) trash containers or any non-radioactive hazardous or biohazardous collection containers or satellite accumulation areas (SAAs) to prevent possible cross-contamination. Radioactive waste containers must be kept secure – many laboratories use locked cabinets to store waste containers or work with Facilities Management to install a locking gate across radioactive waste storage areas.

Training, Education and Experience of the Licensee

The Training, Education, and Experience sections refer primarily to the person applying to be a radiation licensee. These sections may be completed for additional laboratory staff if necessary, but the RSC will mainly be interested in the licensee's experience with radiation. If the RSC does not consider the training, education and experience of the applicant to be acceptable, the licensee may be asked to work under the oversight of a licensee more experienced with radiation for a certain amount of time. Dates should be provided as accurately as possible in these sections, though month and year are sufficient. Radiation Safety Training completed through the CU Radiation Safety Office should be included in the training section, as it is a requirement of the RSC.

All personnel using radioactive materials under the authorization must complete Radiation Safety Training specific to the type of radiation used prior to beginning work with radiation.

License Amendments

Radiation licenses should reflect current needs in each laboratory. As research needs change, licenses may need to be amended to match. Certain changes may be accomplished administratively through the CU Radiation Safety Office, while others require a more formal approval process through the RSC. Amendments to radiation licenses do not change the renewal date of the license unless the licensee updates and corrects information in the entire license (in effect, requesting an early renewal).

Formal license amendments are required for changing radionuclides, experimental procedures, and laboratory locations. The CU Radiation Safety Office facilitates license amendments, which can frequently be approved between RSC meetings if the changes are not significant. Amendments approved by the RSC between meetings are approved on a conditional basis – meaning the work may proceed but will be re-evaluated formally by the Committee at their next regular meeting. Contact the CU Radiation Safety Office by email to request a license amendment.

Laboratories preparing to move to different laboratory facilities should contact the CU Radiation Safety Office as soon as possible to add the new space to the radiation license. Radiation may not be stored or used in a space which has not been reviewed and approved by the RSC.

A new type of radiation use may require laboratory personnel to complete additional Radiation Safety Training specific to the type of radiation (unsealed radioisotopes, sealed sources or x-ray machines, for example) used.

License Renewal

Radiation licenses are issued with an expiration date reflecting a three-year period. Licenses not amended or renewed within the three-year period remain valid until an amendment or renewal is issued. The CU Radiation Safety Office tracks these expiration dates and contacts licensees to request a review and update of license information for each renewal. Renewals are approved at quarterly RSC meetings.

Inactive Licenses

There are periods of time during which a licensee may wish to keep their radiation license but put research involving radiation on hiatus. In this case, the licensee may request to be placed on inactive status. In this situation, all radioactive materials and waste must be removed from the laboratory through the CU Radiation Safety Office, who will perform a final ("exit") contamination survey on laboratory surfaces and equipment. After this, the RSC will review the inactivation request and, if approved, the licensee will be released from regular license requirements such as training and surveying for a three-year period.

If a licensee wishes to actively use radiation again within three years of going inactive, the Radiation Safety Committee can approve a re-activation. Work already approved before the license was inactivated may begin again by contacting the CU Radiation Safety Office. Changes to experimental protocols already approved will be reviewed by the RSC as an amendment to the license.

After three years on inactive status with no radiation work resuming, licenses are terminated by the RSC and the licensee will need to submit a new license application to use radioactive materials in the future.

License Termination

Radiation Licenses no longer in use are terminated. Termination is required for any laboratory leaving the University of Colorado. If a laboratory is relocating or closing, the licensee should contact the CU Radiation Safety Office as soon as possible to facilitate proper relocation and/or disposal of the radiation under the authorization and begin the process of closing of the laboratory. The Department of EH&S should also be contacted at (303) 492-6025 to facilitate proper relocation or disposal of non-radioactive materials.

Licenses of laboratories that are discontinuing work with radiation may also be terminated through the CU Radiation Safety Office.

Apart from these administrative license terminations, a radiation license may be terminated at any time by the RSC for safety or compliance reasons.

Licensee Responsibilities

Radiation licensees are responsible for all aspects of the radiation safety program in their labs and are held responsible by the RSC.

Following is a brief list of some of the responsibilities of a licensee:

- Complete a radiation license application ***prior*** to beginning any work with radiation.
- Request amendments to the radiation license as necessary to ensure the authorization reflects current research needs.
- Update the radiation license for renewal every 3 years.
- Promote a safe working environment and safety culture in the laboratory.
- Designate a Radiation Safety Laboratory Contact and/or Alternate Safety Contact for emergencies.
- Provide supervision of laboratory work and update emergency contact information. This means that Active Licensees who are absent from their lab for a period more than one week need to be in frequent contact with their laboratory safety contact and provide the Radiation Safety Office with contact information in case questions arise while the PI is away.
- Ensure laboratory members receive protocol-specific training to ensure the safe use of hazardous and radioactive materials and familiarity with emergency procedures.
- Ensure the security of all radioactive material (including radioactive waste).
- Ensure that all lab personnel complete required radiation safety training prior to work with radiation and on a timely basis thereafter.
- Ensure the proper use and exchange of dosimeters when necessary.
- Ensure performance and accurate documentation of contamination surveys when required.
- Ensure that any radioactive contamination discovered in the laboratory is remediated in a timely manner and documented as required.
- Report any personnel contamination to the CU Radiation Safety Office immediately.
- Ensure compliance with all regulations, University policies and license commitments.

Laboratory Signs and Labels

Certain signs and labels are required by regulation to be posted to notify others of the presence of radiation in laboratory areas. Many required signs and labels can be obtained through the CU Radiation Safety Office, though some will need to be ordered separately from laboratory safety supply vendors.

Entrances and doors to laboratories using unsealed radioisotopes should have signs posted to warn users of the presence of radioactive materials. These signs are provided by the CU Radiation Safety Office because the regulations are specific about size, color and wording. For unsealed radioisotope laboratories, each door will likely have a sign reading "Caution Radioactive Material" with the radiation

trefoil. This sign should be visible whether the door is open or shut, so may need to be placed on each side of a door. Laboratories using X-ray machines or sealed sources may be provided with signs specific to those hazards for posting.

Each laboratory door should also have an Emergency Notification sticker and the contact information on this sticker should be kept up-to-date.

All radiation laboratories are required to have a Notice to Employees posted in a conspicuous location, easily accessible to laboratory personnel who use radiation. These notices may be obtained by the CU Radiation Safety Office and should not be moved or removed without contacting the Radiation Safety Office.

Equipment or cabinets in which radioactive materials are used or stored should also be labeled with the radiation trefoil and the words "Caution Radioactive Material." Stickers in various sizes may be obtained from the CU Radiation Safety Office for this use. Equipment containing radioactive sources and x-ray machines should have clear and visible warning labels.

Laboratory Audits

As one method of assessing radiation safety on campus, the RSC tasks the CU Radiation Safety Office with performing regular compliance audits in each radiation laboratory. These audits review security of materials, radiation safety training, contamination survey documentation, safe practices, radioactive waste disposal and other radiation safety issues to ensure compliance with regulations and the University Radioactive Materials License. Audits are usually unannounced and occur at least annually. Licensees are given an opportunity to review and respond to any findings with planned corrective actions. All findings and licensee responses are shared with the RSC, which may require additional actions.

In addition to formal annual laboratory audits, the CU Radiation Safety Office frequently visits radiation laboratories to perform contamination survey spot-checks, review contamination survey documentation and evaluate radiation waste areas or update radioactive material inventories. Safety or compliance concerns noted during any laboratory visit may be shared with the RSO and/or RSC.

Regulatory Inspections

As a requirement of the University Radioactive Materials License, both campuses are formally inspected by regulators from CDPHE to ensure compliance with the Rules and Regulations pertaining to Radiation Control. These inspections may occur at any time but are expected at least every 3 years. Formal regulatory inspections include a review of records, interviews with personnel, and visits to radiation laboratories where inspectors may interface with laboratory personnel. The University must correct and respond to any items of non-compliance noted by these inspectors and certain violations may include enforcement sanctions affecting radiation use at the University as a whole.

It is important that each laboratory do its part to maintain the safe and compliant use of radiation to ensure the continued ability to use radiation in research at the University of Colorado.

Radioactive Materials Management

The management of radioactive material is the responsibility of the licensee under whose authorization the material) is used. Ultimately, however, each member of the laboratory is responsible for helping maintain the safe storage and use of the radioactive material in their area. By using correct procedures to order, store, and dispose of radionuclides, sealed sources, and radiation producing machines, each researcher helps implement the ALARA Program and ensure safety at the University of Colorado.

Purchase of Radiation

The CU Radiation Safety Office must approve all radiation brought to the University of Colorado. This includes items purchased from vendors, obtained from colleagues, obtained from other institutions or materials received from internet websites.

In most cases, a Purchase Request or Standing Purchase Order is set up to order radioactive materials and this is approved by the CU Radiation Safety Office prior to the order. A basic requirement for this approval is the existence of an active radiation license for the materials which includes appropriate authorization for the radiation ordered. Procurement cards should not be used to purchase radioactive materials without prior approval from the CU Radiation Safety Office.

All radioactive materials need to be delivered directly to the CU Radiation Safety Office, as there are regulatory requirements governing the transportation and receipt of radioactive materials. Special arrangements for laboratories at the Colorado Springs campus may be made on a case-by-case basis with the CU Radiation Safety Office.

Please verify the use of the following shipping address when ordering radioactive materials:

CU Radiation Safety Office
1000 Regent Drive, 413 UCB
Boulder, CO 80501
Attn: Licensee Last Name

The CU Radiation Safety Office ensures regulatory requirements are met and that proper radiation authorization is in place prior to delivering radioactive materials to a laboratory. Department of Transportation regulations require that packages containing radioactive materials be checked for contamination within a certain timeframe after delivery from the carrier. If the radioisotope vial is contaminated, the laboratory will be notified to use extra caution when handling. In the rare case of a large amount of contamination, the vial may need to be disposed by the CU Radiation Safety Office and the laboratory will need to request a replacement from the vendor.

Radioactive materials will not be delivered to a laboratory if the material will cause a radiation license limit to be exceeded. If a limit is exceeded, a license amendment or disposal/removal of current inventory may be necessary, and this may delay delivery of the materials to the laboratory. Delivery of radioisotope

may also be delayed if the licensee and/or laboratory personnel are past due for Radiation Safety Training.

Large equipment such as x-ray machines may be delivered directly to the laboratory with prior approval from the CU Radiation Safety Office.

Radioactive materials that are purchased, donated, received as gifts, or transferred from other institutions must be delivered to either campus through the CU Radiation Safety Office.

Storage and Use of Radioactive Materials

Cabinets, freezers and all other equipment used to store radioactive materials must have a *Caution Radioactive Materials* sign or label with the radiation trefoil visible. Radioactive materials should be stored only in areas properly marked and approved for their use. Storage equipment should be equipped with a lock to ensure security of the material.

Designated Radiation Use Areas

Radioactive materials should be stored and/or used only in designated areas. If materials need to be moved to another room, the radiation license will need to be amended to include the new space. Security requirements remain the same for all radiation use areas and required signs and labels need to be posted.

It is also a good idea for laboratories to designate an area(s) for eating, drinking and food storage outside of the laboratory.

Security of Radioactive Materials

Each laboratory must ensure the security of radioactive materials and/or radiation-producing machines. The following security procedures should be in place in all laboratories using radioactive materials:

- Doors to the laboratory should be locked if no one is present
- Strangers to the laboratory should be challenged.
- Radiation storage and use areas should be consolidated and minimized whenever possible.
- Radioactive materials removed from secure storage should always be under direct observation ("line of sight") by a member of the laboratory who has completed radiation safety training.
- Storage cabinets and refrigerators/freezers containing radioactive materials (stock vials and aliquots of radioisotope, as well as sealed sources) must be locked when not actively in use.
- Radioactive waste containers should be closed and kept secured when not actively in use.

Radioactive Materials Inventory

Radioactive material inventories are tracked through a database system. The CU Radiation Safety Office provides a printed inventory of unsealed radioactive materials to each laboratory using these items on a quarterly basis. This inventory should be kept on the outside of the main storage freezer/refrigerator/area in each laboratory. As a vial of radionuclide is used and disposed, the

identification number on the outside of the pig should be crossed off the inventory. The individual disposing of the item should also date and initial the inventory sheet.

Each quarter, laboratories should compare the vials physically present in the freezer/ refrigerator/ area with the printed inventory to ensure accuracy. Vials which are no longer used or have decayed too far for use should be placed in an appropriate waste container and removed from the inventory list. The inventory sheet is collected by the CU Radiation Safety Office and reconciled with the database to update each laboratory's possession levels. Radiation vials are also added to the laboratory inventory in BioRAFT as they are received and may be updated by the laboratory as they are used.

It is a good practice to dispose of radioactive materials which are more than one or two years old, especially those bound to nuclides and proteins. Some bound radioactive materials and their chemical carriers have an effective "shelf-life" that may be exceeded. With certain long-lived radionuclides, especially tritium, the practice of periodically purging them helps reduce contamination problems in the storage area. It is not recommended that any vial of isotope be kept on the inventory longer than ten years.

Transfer and Transport of Radioactive Materials

Radioactive materials and/or radiation-producing machines may be transferred to another appropriately licensed laboratory in the same building, following approval from the CU Radiation Safety Office. Once approval from the CU Radiation Safety Office has been arranged, laboratory personnel may be given permission to move the materials from one laboratory to another. All materials should be packaged securely and placed in secondary containment for transport to avoid spills and/or contamination.

The radioactive material must be transferred to the license and included in the *Radioactive Materials Inventory* of the recipient laboratory. If the recipient is not authorized for the material being received, a license amendment from the RSC will be necessary prior to the transfer being approved. Transfers between buildings must be arranged through the CU Radiation Safety Office to ensure safe handling and transport. The CU Radiation Safety Office transports all radioactive materials between buildings on campus to ensure proper Department of Transportation regulations are followed.

Periodically, laboratories may wish to send radioactive materials off-campus to a collaborator, other institution, or field location. Radioactive materials are not to be shipped off-campus without the prior approval of the Radiation Safety Officer.

To send material off-campus, the user should carefully package the material to avoid damage and request a pick-up by the CU Radiation Safety Office, who will address the radiation packaging and shipping requirements. Include a list of the package contents, name and address of the sender and receiver, Federal Express account number (if necessary/available), and any special instructions.

In many cases, authorization and/or NRC reciprocity paperwork is necessary which may cause lengthy delays - please plan accordingly. This is especially true for international shipments. The licensee wishing to ship the material arranges for payment of all shipping costs.

If the Department of the laboratory wishing to ship materials has a shipping manager/office, they need to be in contact with the Radiation Safety Office to assist with the shipment of materials. The campus Office of Export Controls may also need to be involved. PIs are responsible for notifying all entities of the shipment.

Safe Use of Radioactive Materials

Certain practices are recognized as good ways to ensure radioactive materials are being used safely.

General Laboratory Housekeeping Rules

- Radiation should only be used in designated areas with proper shielding and equipment available.
- Surfaces to be used with radioactive materials should be covered with bench paper to make decontamination easy. Alternately, radioactive materials may be used on a surface which is easily decontaminated. Mark radiation use areas and surfaces with the radiation trefoil to warn others of the presence of radiation.
- Strive to keep all laboratory experimental areas as clean and neat as possible. Messy areas may contribute to the spread of contamination and give the impression that the lab does not value safety.
- No service or other animals should be present in laboratories using unsealed radioactive materials out of concern both for the health of the animal and for the likelihood of the spread of contamination.
- Do not use radioactive materials in areas which may cause an unexpected release to the environment, such as fume hood with drains or sinks. Drain disposal of liquid radioactive waste from laboratories is not allowed at the University of Colorado.

Use Proper Personal Protective Equipment (PPE)

- Personnel should wear lab coats and/or other protective clothing at all times when working with radioactive materials. Long pants and closed-toed shoes are strongly recommended while short pants and/or sandals are strongly discouraged.
- Wear at least one pair of disposable gloves at all times while handling radioactive materials. When working with more volatile materials such as tritium, double-gloving is a good idea. Remember to only dispose of gloves which may have come into contact with radioactive materials into the appropriate solid waste container.
- Wear safety glasses or googles when working with any radioactive material that has splash potential.

Monitor for Contamination and Personnel Exposure

- After each procedure, monitor your hands and feet for contamination using an appropriate portable radiation survey meter before leaving.
- Wear appropriate dosimeter(s) at all times while working with or near radioactive materials. When not being worn to monitor personnel exposures, dosimeters should be stored in a low-background area.
- Survey all radiation work areas, the floor, door handles, hood sashes, equipment, etc. for contamination using wipe smears. These surveys should be conducted weekly when radioactive materials are used.
- Perform an area survey periodically before, during, and after each experiment using an appropriate portable radiation survey meter to monitor for levels of increased radiation.
- Record all survey results and keep LSC printouts in an easily accessible binder or logbook in the laboratory. If possible, include a map of the laboratory and areas surveyed.

Store and Dispose of Radioactive Materials Properly

- Dispose of radioactive waste only in designated, labeled, and properly shielded containers. Waste containers should be closed and kept secure when not in use.
- Store liquid containers in secondary containment tubs.
- Complete an entry on the *Container Contents Sheet* each time waste is placed in a radioactive waste container.
- Reserve the initial rinse of contaminated glassware as liquid radioactive waste. Radioactive materials may not be discharged to the sanitary sewer from laboratories on campus.

Reduce the Chance of Internal Contamination

- Never eat, drink, smoke, or apply cosmetics in any area where radioactive or materials or chemicals are used or stored. Areas for eating and drinking should be designated outside the laboratory.
- Do NOT store food, drink, or personal effects in areas where radioactive materials or chemicals are used or stored. It's a good idea to not even dispose of or store empty food and beverage containers in a radiation laboratory, even if it was consumed elsewhere.
- Never pipette by mouth, especially with radioactive materials.
- Radioisotopes more likely to be internally ingested may require special procedures. For instance, iodinations using unbound radioiodine must be performed in a special hood fitted with a HEPA filter at the CU Radiation Safety Office. This type of work typically involves *in vivo* (or bioassay) tests to determine whether the radionuclide was internally deposited.

Use Proper Shielding

- Certain work with radioactive materials may require shielding to lower the radiation exposure to laboratory personnel. Appropriate shielding should be used for each type of radiation used. In general, ¼ inch of Plexiglas is appropriate for ^{32}P and other strong beta emitters.
- The use of lead to shield ^{32}P is discouraged because beta particles produce Bremsstrahlung x-rays when stopped with a dense material.
- The CU Radiation Safety Office can assist in selecting appropriate shielding.
- While radiation licensees are responsible for providing appropriate shielding for the use of laboratory personnel, the CU Radiation Safety Office may have excess shielding materials available for laboratory use.

Practice good ALARA techniques

- Reduce the amount of time spent near radioactive materials by doing several "dry runs" of the experimental protocol without the radiation.
- Do not stand or work near waste containers which may be emitting radiation
- Do not shield strong beta emitters with high atomic number (heavy) materials such as lead. Use Plexiglas or other less dense material to shield beta particles.
- All laboratory personnel should be aware of the presence of radiation in the laboratory and be familiar with emergency procedures for any radioactive or hazardous materials used in the area.

Radiation Surveys

To ensure that radioactive contamination and/or exposure levels are as low as reasonably achievable (ALARA), surveys for radiation are completed in areas where radioactive materials or radiation-producing machines are used.

Contamination surveys are performed with **wipe smears** and are used to detect removable radioactive contamination from unsealed radioisotopes such as ^{32}P or ^{35}S. Access to a liquid scintillation counter (LSC) or gamma counter is usually necessary to analyze wipe smear samples. Wipe smear samples analyzed with an LSC must contain biodegradable scintillation cocktail in the vial. Dry samples are not acceptable for contamination surveys.

Area surveys, performed with an appropriate survey instrument such as a geiger counter, are used to measure exposure levels from radiation with a high enough energy to be detected. Area surveys are performed in laboratories using x-ray machines or some sealed sources and should be performed in conjunction with contamination surveys in laboratories using certain unsealed radioactive materials.

Contamination Surveys

Some guidelines regarding contamination surveys:

- All laboratories should be kept clean to minimize the potential for contamination.
- Surveys should be taken on a regular basis to detect any contamination occurring from radiation work and to help prevent the spread of contamination which may then be tracked or even ingested by laboratory personnel. It is a good practice to take surveys after each experiment, but this is not always feasible.
- A wipe smear test **IS required** by regulation to be taken following any experiment involving >1 mCi of ^{32}P. This should be recorded in the laboratory survey logbook.
- Wipe smear surveys must be taken in each lab using unsealed radioactive materials every week that radiation is actively used.
- If radiation is not being actively used in a laboratory, the area around any radiation storage area (such as freezers or waste containers) must be surveyed monthly.
- Survey results are reported to the CU Radiation Safety Office each month, using the following website: http://ehsonline.colorado.edu/radsurveys/
- Documentation of surveys, including LSC print-outs, a print-out of the survey submittal page, and notes regarding the decontamination of “hot spots” needs to be kept in a logbook or other easily accessible location in the laboratory. This logbook will be reviewed by auditors and regulatory inspectors.
- Taking area surveys with a survey meter is a good practice but does not replace the requirement to complete contamination surveys using wipe smears.
- Laboratories should maintain an adequate supply of decontamination supplies, including a strong detergent (special formulas are sold for this purpose, with trade names such as “RadiacWash” or “IsoClean”), disposable gloves, and plenty of paper towels.

How to Conduct Contamination Surveys

- The laboratory contamination survey should include equipment and work areas used during the experiment as well as areas which may have been accidentally contaminated by the researcher.
- Examples of areas that should be included in a contamination survey include: floors (especially near waste containers, desks, and doorways or any floors between lab rooms where radioactive samples were transported); doorknobs; telephone receivers; buttons on equipment; hood sashes, edges, handles and switches; sink handles, edges, and drains; and lab benches.
- Many laboratories simply use filter paper to perform wipe smears. Numbered paper wipes are also available from the CU Radiation Safety Office.
- Results should be reviewed as soon as possible so that any contamination can be remediated without delay.
- The CU Radiation Safety Office defines "contamination" as any wipe smear analysis that reads more than twice the level of a background/blank sample.
- A good practice is to re-analyze a sample which reads more than twice background to eliminate the possibility of a false positive.
- If the contamination level in an area is more than twice background, e.g. if a sample reads 101 cpm when the background/blank sample reads 50 cpm, even after the sample is re-analyzed, decontaminate the area and re-survey. When decontaminating an area:
    - Wear proper PPE, including labcoat and disposable gloves. If contamination is on the floor, disposable booties may be useful. Be careful not to track contamination by walking around the lab or through hallways.
    - Use a decontamination solution (such as RadiacWash or IsoClean) or a strong detergent to saturate the contaminated area. For some radionuclides, a survey meter may be helpful in narrowing down areas of contamination.
    - Clean the area with paper towels, wiping from the outside to the inside to prevent further spreading the contamination.
    - Dispose of all clean-up materials in an appropriate radioactive waste container.
    - Take wipe smears of the area to check decontamination progress. If more than twice background, repeat cleaning process.
- Continue this process until the area is clean (less than twice background).
- Both initial and final survey results should be included when submitting report of contamination surveys to the CU Radiation Safety Office. All records and results should be stored in laboratory survey logbook.
- Contact the CU Radiation Safety Office for assistance with areas that are not able to be decontaminated.

Surveys should be completed each week that radioisotope is used to detect any contamination occurring from radiation work. *A week is defined as 7 days beginning Sunday and ending Saturday.* Each licensee using a "common room" is responsible for performing and recording surveys of the common room. An exception may be granted through the CU Radiation Safety Office regarding inter-laboratory agreements

to conduct surveys of common rooms. Surveyors should use wipe smears and a LSC with scintillation cocktail or, for certain isotopes, a gamma counter to analyze the results of the survey.

In some labs, the person tasked with completing contamination surveys may not actively work with radioactive materials in other laboratory protocols but should complete Radiation Safety training for unsealed isotope users anyway, so they are aware of the hazards of radiation contamination.

The CU Radiation Safety Office may perform secondary contamination surveys as well as exit surveys of laboratory areas where work with radionuclides has been discontinued. The secondary survey may include areas in which the laboratory personnel do not think radioactive contamination is likely to be found. Laboratories will be notified if contamination levels exceed the level of 100 dpm/100 cm^2 and will be asked to decontaminate and re-survey the area. If the contamination found is at a high enough level, the laboratory may be given a certain time frame to complete decontamination before the CU Radiation Safety Office performs a re-survey of the area.

Wipe smears are also used to perform leak-testing of radioactive sealed sources, which is required at certain intervals according to the isotope and activity of the source. The CU Radiation Safety Office performs and tracks leak tests on sealed sources at the University of Colorado.

Area Surveys

For high-energy beta and any gamma emitters, area surveys may be conducted with a portable (hand-held) radiation survey meter in addition to routine contamination surveys. Area surveys are used to monitor for levels of increased radiation in areas where radioactive materials are unshielded or during relocation of radioactive materials. It is important to document a background radiation survey value for comparison to the measured radiation result by writing down the reading on the meter face, along with helpful information such as distance from the surface/radiation source.

Laboratories using unsealed radioactive materials should perform area surveys periodically before, during, and after an experiment. As part of this survey, be sure to check floors and regular trash containers for radioactive contamination which should not be there. A final area survey after completion of an experiment does not eliminate the requirements for taking wipe smears for the contamination survey mentioned previously. Results may be recorded in the laboratory logbook used to store contamination survey results.

Laboratories primarily using x-ray machines and/or sealed sources should perform periodic area surveys using an appropriate survey instrument. This survey should be performed while the radiation-producing machine is “on” to determine if there is any leakage of x-rays. The results of the survey should be noted in a log and maintained in an easily accessible location for review by auditors.

Instruments Used for Radiation Surveys

Portable survey instruments such as Geiger Counters

Each laboratory using unsealed medium-to-high-energy radioactive material (low-energy beta emitters such as ^{3}H or ^{14}C cannot be detected by a Geiger counter) should either have two portable radiation survey instruments in the laboratory or possess one instrument and have access to a second in a nearby laboratory. Arrangements should be made in advance to borrow a back-up instrument from another laboratory. Having at least two instruments available helps ensure the availability of a survey instrument if one is damaged, out of calibration, or otherwise unable to be used.

While appropriate survey instruments must be available for activities involving radiation at the University of Colorado, it is the responsibility of each laboratory to supply the instrument(s). Ideally, the instrument should read in units of mR/hr and/or counts per minute (cpm) and the probe should be one which is most appropriate for the type of work performed in the laboratory. The CU Radiation Safety Office is available to assist with appropriate instrument selection and has a limited supply of loaner meters available for temporary use.

Each time a portable survey instrument is used, make sure it is functioning properly. Check for battery level, determine a background count rate and confirm that the instrument responds to a known radiation source. The probe of a Geiger counter should be held approximately 1 cm from a surface to be surveyed and moved very slowly to allow time for the instrument to respond. The efficiency of the reading is highly dependent on factors such as the energy of the radionuclide being detected, the distance between the probe and the material, and the speed and geometry of the probe while surveying.

The CU Radiation Safety Office maintains a database of all survey instruments on campus and provides calibration services for most of the models used at the University of Colorado. Calibration is required at least once each year. To ensure compliance with the annual requirement, the CU Radiation Safety Office collects and calibrates survey instruments every six months. Contact the CU Radiation Safety Office if you notice a survey instrument has not been calibrated in the past six months. If a laboratory obtains a new instrument, contact the CU Radiation Safety Office as soon as possible to have it placed on the calibration schedule.

Instruments which require major repair or more complicated calibration techniques will be sent to the manufacturer for these services at the expense of the laboratory. Minor repairs may be provided by the CU Radiation Safety Office at little to no charge to the laboratory, depending on time required or parts used.

Survey instruments/meters are calibrated to a National Institute of Standards and Technology (NIST) traceable ^{137}Cs gamma source. Correction factors are indicated on the calibration label for use with beta emitting radionuclides. When using beta emitters, multiply the reading on the instrument by this correction factor to obtain an accurate reading.

Liquid Scintillation Counters and Gamma Counters

Laboratories using unsealed radioisotope are required to perform regular contamination surveys and therefore should have access to a working Liquid Scintillation Counter (LSC). If a laboratory only uses gamma emitting radioisotopes, a Gamma Counter may be used to measure survey wipes.

Due to the expense of these instruments, the CU Radiation Safety Office actively works with laboratories to ensure availability across campus. However, a LSC may not be available for all campus areas and arrangements will need to be made to send or transport wipe tests to another department for analysis.

The CU Radiation Safety Office performs annual calibration checks on campus LSCs, but each user should check that the instrument is functioning properly each time the instrument is used. If the blank sample reads unusually high, it can indicate a problem with the instrument. However, the first step to take when unusually high readings are noted is to "dark adapt" the samples by leaving the scintillation vials inside the LSC with the lid closed for 20-30 minutes before running the samples again. Frequently, and especially with plastic vials, static can build up on the samples and look like a low-energy radioactive emission to the instrument, which then reports a false positive result.

Freezer Frost Surveys

Freezers used to store tritium (^{3}H) frequently become contaminated due to hydrogen exchange with water in the frost or condensation of the freezer. A heavily contaminated freezer can contain several mCi (MBq) of tritium water (HTO) in the frost, which may spread contamination to the laboratory floor when samples are removed from the freezer.

Freezers used to store tritium (^{3}H) are checked every six months by the CU Radiation Safety Office. Be sure to contact the CU Radiation Safety Office if tritium is stored in a different freezer than usual, so that it can be added to the survey rotation. Excessive contamination (≥10,000 dpm/100 cm^2 or dpm/ml) requires defrosting and decontamination of the freezer by laboratory personnel. Any liquid generated by defrosting should be considered radioactive liquid waste and collected for disposal through the CU Radiation Safety Office. Paper towels and gloves used during the defrost should be disposed as solid radioactive waste. Be sure to place pans and absorbent paper on the floor around the freezer to catch water leakage during the defrosting process. Use pans to collect ice chunks and let them melt in a fume hood before decanting into radioactive liquid carboy. Check for residual contamination with wipe smears on the outside of the freezer and floor after defrosting process.

Because of the high likelihood of freezer contamination, the CU Radiation Safety Office encourages laboratories to dispose of tritium (^{3}H) that is not being used.

Equipment Transfer, Disposal, or Resale Surveys

Equipment such as refrigerators, freezers, centrifuges, and other laboratory items used with radioactive materials must be surveyed prior to transfer or disposal to assure that they are free from radioactive contamination. Refrigerators and freezers used to store tritium may have become contaminated when radioactive hydrogen became incorporated into the plastic of the unit, for example. Contact Property

Services/Distribution to arrange for transfer or disposal of equipment associated with radioactivity and perform contamination surveys of both the inside and outside of the unit. Maintain the survey records, including LSC print-outs, with the contamination survey results in the laboratory survey logbook. Once the unit is determined to be free from radioactive contamination, all radioactive signs and symbols must be obliterated or removed prior to disposal.

Equipment such as liquid scintillation counters which contain radioactive sources should have the source and any lead shielding removed by the manufacturer prior to disposal. This can be arranged through the CU Radiation Safety Office, who will dispose of the radioactive source. No radioactive sources may be sold or transferred to another person or entity without the CU Radiation Safety Office confirming the recipient has the proper authorization.

Radiation-producing machines should have the x-ray tube removed and/or destroyed prior to disposal. All radioactive signs and symbols must be obliterated or removed. Contact the CU Radiation Safety Office to notify of any x-ray machine disposal so that the proper forms may be filed with the CDPHE X-ray Certification Unit.

Radioactive Waste Management

Most laboratories on campus using unsealed radioisotope generate radioactive waste. Waste that is non-hazardous other than the radioactive component is considered purely radioactive waste. Some experimental protocols involve the use of hazardous materials along with the radiation. Waste with more than one hazard is referred to as mixed waste. Mixed waste is much more expensive to dispose and can be more harmful to the environment. If possible, laboratories should work with the CU Radiation Safety Office to minimize the production of mixed waste.

Proper handling of wastes is critical for appropriate transportation and disposal. There are numerous Federal, State, and local regulations which impact transportation and disposal of radioactive waste and all requirements must be followed. Mixed waste must comply with both radioactive and chemical regulations.

Radioactive waste at the University of Colorado is separated by waste type (solid, liquid, and scintillation vial) and by half-life. The CU Radiation Safety Office provides containers for all radioactive waste and picks up the waste when pickup request is received from a laboratory. Any container used to store radioactive waste must be marked with the radiation trefoil, along with isotope and general activity inside the container. Support and custodial staff are trained to look for the radiation trefoil regardless of native language.

Waste minimization is an especially important concept with radioactive waste. Purely radioactive waste containing long-lived radioisotope must be sent to one of a very few low-level radioactive landfill in another state. Certain regulations must be followed and permits acquired before waste can be shipped off-site from the University. Therefore, laboratories should actively seek ways to reduce the amount of radioactive waste generated. The CU Radiation Safety Office covers the cost of radioactive waste disposal, but if a laboratory generates a particularly expensive waste, some or all of the disposal cost may be re-charged to the laboratory. Some examples of how to minimize waste include:

- Use biodegradable scintillation cocktail instead of flammable scintillation cocktail. If there is a legitimate need for the use of flammable scintillation cocktail, contact the CU Radiation Safety Office.
- If a there is a choice between two different radioisotopes to use in an experiment, choose the one with the shortest half-life.
- Be conscientious of what you put into a radioactive waste container. Don't use it for non-contaminated regular trash if you can avoid it.
- Segregate areas where radioactive containers are stored from regular trash containers and from hazardous material satellite accumulation areas to reduce the change of cross-contamination.
- Request a separate waste container from the CU Radiation Safety Office for a waste stream containing hazardous materials, rather than mixing it with the purely radioactive waste.

Mixed waste generators must complete Hazardous Waste Generator Training in addition to Radiation Safety Training.

Mixing biological wastes and radioactive material should be avoided whenever possible. If necessary, protocols which involve the use of both radiation and biological materials should include a step allowing for inactivation of the biological agent prior to disposal in radioactive waste. **When radioactive material is involved, use of an autoclave is NOT permitted**. Once rendered non-infectious, this waste should be segregated from all other radioactive wastes. **Do not use biohazard bags for radioactive materials**. The CU Radiation Safety Office should be notified before this type of waste is produced.

Radioactive Waste Containers

Radioactive waste is generally separated into three types: solid, liquid, and scintillation vials, each designated a specific waste container. When not actively in use, radioactive waste containers must be kept secure. Most laboratories store their waste containers in a lockable cabinet or install a locking gate to secure the waste container area.

Solid Radioactive Waste

Solid waste containers are available in two sizes, a twenty-gallon size which looks like a trash can, and a five-gallon size which looks like a covered metal bucket. Solid waste containing radioisotopes with a 90-day half-life or less will be held-for-decay before disposal. Once the waste has decayed to a level below background it will be released to a non-radioactive landfill. Keep this in mind when placing waste in the container. Minimize the radiation symbols used on bench paper, for instance, so that the waste doesn't have to be sent to a radioactive landfill for no real reason.

Occasionally, enough activity is disposed into a metal solid radioactive waste can that higher-than-background exposure readings are detectable outside the waste container. Usually these readings are due to the denser metal of the can stopping a high-energy beta emitter and generating Bremsstrahlung x-rays. Shielding can be placed around the can to reduce the exposure level if necessary.

Liquid Radioactive Waste

Liquid radioactive waste containers are available in two sizes, a five-gallon, round plastic carboy not to be confused with the cube-like carboys used for chemical wastes, and a one-gallon, round plastic bottle. Smaller containers are available upon request for small amounts of liquid waste. Secondary containment tubs large enough to hold the entire contents of the liquid waste carboy in the case of a leak are strongly recommended for liquid waste containers and must be provided by the laboratory. Radioactive waste containers should be kept closed when not in active use – funnels will need to be put in the container when needed, not left sitting in an open container.

Aqueous radioactive liquid waste is disposed in a different way than non-aqueous wastes and these should be kept separate if possible. Contact the CU Radiation Safety Office for specific guidance.

Drain disposal of liquid waste from laboratories is not allowed at the University of Colorado, and care should be taken to avoid the possible accidental release of waste to the sanitary sewer via fume hood

drains, floor drains or sinks. Similarly, evaporation of liquid radioactive waste in fume hoods is not allowed.

Scintillation Vial Waste

Scintillation vials are collected in one size of waste container, a five-gallon covered metal bucket. This container looks the same as the small solid waste container and care must be taken to avoid confusion between these containers.

Other Waste Containers

Containers are also provided for radioactive sharps, lead pigs, and any other unusual wastes. Empty lead pigs (**pigs** are the containers used to transport and shield vials of radioisotope or sealed sources) are stored separately and collected upon request for possible recycling by the CU Radiation Safety Office. Plastic pigs may be disposed in the appropriate solid waste container if there is no lead liner inside the pig. The CU Radiation Safety Office can offer more guidance or provide special containers when necessary.

Waste Segregation by Half-life/ Container Color

Radioactive waste is also segregated by half-life at the University of Colorado. To make this process easier in the laboratory, the three half-life categories are designated by color.

The half-life categories are as follows:

Yellow: P-32, P-33, Rb-86 and other radionuclides with half-lives < 60 days

Orange: S-35, I-125 and other radionuclides with half-lives > 60 days but < 90 days

Green: H-3 and C-14 and other radionuclides with half-lives > 90 days

Waste in yellow and orange categories is held-for-decay by the CU Radiation Safety Office, as allowed by federal regulations. Half-life categories are very important for waste minimization and decreasing disposal costs for the University. Waste should be **segregated by half-life** category whenever possible and placed in the appropriately colored waste container. If waste is created containing two or more isotopes from different half-life categories, the waste should be disposed in the container for the longest-lived isotope in the waste. For example, waste containing ^{35}S (87 day half-life) and ^{14}C (5,730 year half-life) should be placed in a green waste container.

Waste Disposal Guidelines

Keep in mind the following restrictions when disposing of radioactive waste:

- Radioactive Sharps (glass pipettes, needles, scalpels, razor blades) should be placed in sharps containers designated for radioactive sharps and not in any other type of waste container. Sharps do not require segregation by half-life. Razor blades should not be disposed with gels in solid waste but placed into a separate radioactive sharps container.
- Lead pigs should be collected separately. Boxes for this purpose are available from the CU Radiation Safety Office.

- No more than 10 ml of liquid total should be placed in a solid waste container.
- Scintillation vials (even if empty and/or non-contaminated/ “clean”) have their own waste container. Solids other than scintillation vials and/or liquids other than liquid scintillation cocktail should not be placed in the scintillation vial container. Scintillation vials do not have to be emptied – the entire closed vial with cocktail should be placed in the scintillation vial container. Scintillation cocktail should not be disposed with radioactive liquid waste.
- Mixed wastes of different types should be segregated and minimized as much as possible to facilitate disposal. Smaller waste containers are available from the CU Radiation Safety Office upon request.
- Waste containers should be kept closed and secure at all times, unless waste is actively being added.
- Contact the CU Radiation Safety Office with questions concerning items not specifically addressed in this list.

Waste Documentation

Each radioactive waste container from the CU Radiation Safety Office is provided with a Container Contents Sheet which is color-coded to correspond with the decay categories used to separate waste by half-life. The color copies were implemented to facilitate identification with a given container in laboratories having multiple decay categories. If you need additional Container Contents Sheets, copies are acceptable, and the color coding is not required. Once waste is added to a container, all contents need to be recorded on the Container Contents Sheet. Additional copies are available from the CU Radiation Safety Office if necessary.

The Container Contents Sheet is designed so that an entry can be made on the sheet each time that waste is placed into the container, and the contents can be easily totaled for disposal. The entries should detail the amount added, constituents, radionuclide and activity, and the initials of the waste generator. Full chemical names, in English, should be used for each constituent. Do not use abbreviations. If there is any waste in the container, there needs to be an indication of at least the isotope and activity on the Container Contents Sheet.

All radioactive waste stored on bench-tops or outside of provided radioactive waste containers should be marked with isotope and a general idea of activity (“P-32 <1 uCi” is acceptable) along with a radiation trefoil. It is a best practice to empty benchtop waste containers into the secured larger waste containers at the end of each work day.

Waste containers should be submitted for pickup before they are full. Over-full containers will not be able to be picked up and the laboratory will be asked to separate the waste into two containers. Plan ahead for the time it takes to schedule a waste pickup, which may take up to a week. The CU Radiation Safety Office can bring extra containers before the next scheduled pickup if necessary.

When the waste container is prepared for pickup, the individual entries from the waste generators should be totaled and the separate total section of the Container Contents Sheet completed by an appropriately trained waste generator. Prior to pick-up by the CU Radiation Safety Office, the waste generator must survey the exterior of each container for contamination using a wipe smear and LSC analysis. The result of the wipe smear survey should be recorded on the Container Contents Sheet. Each sheet must be signed by the generator. This Generator Certification is required by regulation and includes confirmation that the generator has completed appropriate Radiation Safety training. Waste will not be picked up if the wipe test section or generator certification signature are not completed.

Requesting Pickup of Radioactive Waste

When a waste container is full, a pick-up may be requested from the CU Radiation Safety Office. Waste containers which are not full but are not likely to be used within a short time frame should also be submitted for pickup. To request a pick-up, the generator or laboratory representative requests a waste pickup on the EH&S website (ehs.colorado.edu). Requests must be received by the CU Radiation Safety Office before noon on the day preceding the next scheduled pick-up to allow for proper paperwork generation.

The Radioactive Waste Pick-up Request webform summarizes the information for the containers that need to be collected including the total volume of each container, radionuclide, total activity, constituents and total percentages of each constituent (which must total 100%), and pH for liquids. Indicator paper is acceptable for determining the pH value. Unless otherwise requested, each container collected will be replaced with an empty container of the same type and size.

Radiation Safety Training

The University RSC requires the successful completion of radiation safety training prior to any work with radioactive materials or x-ray machines. Radiation safety training covers the following topics, by regulation:

- Basic radiation units
- Basic radiation safety concepts,
- Regulatory limits and requirements,
- Dose and exposure control techniques, and
- Rules specific to the institution.

Training from other institutions cannot be accepted to meet the requirements of the University of Colorado Radioactive Materials License.

Once initial training has been completed, refresher Radiation Safety Training is required every three years to continue working with radioactive materials at the University of Colorado. This interval has been established by the RSC and is subject to change. Users of X-ray machines must complete refresher training annually, according to the Colorado Rules and Regulations Pertaining to Radiation Control.

Radiation Safety Laboratory Contacts, Dosimetry Contacts and Survey Contacts are welcome to arrange one-on-one sessions to receive more information about these roles with staff from the CU Radiation Safety Office.

Radiation Safety Training Modules

Satisfactory completion of radiation safety training is required by anyone planning to use unsealed or sealed radioactive materials and/or x-ray radiation at the University of Colorado. It is the responsibility of the radiation licensee to ensure that radiation safety training is completed in a timely manner by laboratory personnel working under their authorization. Training completion is considered successful if the final exam is completed with a score of 80% or above. Radiation safety training is required before Radiation Licenses can be approved by the RSC, and before dosimeters may be issued to personnel.

Information and techniques specific to a laboratory or experimental protocol is not covered in radiation safety training modules and this instruction should be provided by the radiation licensee. Modules for specific uses of radiation at the University of Colorado are available online, at colorado.bioraft.com. Personnel without an identikey will need to request a temporary account from the CU Radiation Safety Office to access BioRAFT. Researchers using more than one type of radiation will need to complete all corresponding modules.

Radiation safety training modules available:

- Radiation Safety Training for Unsealed Radioisotope Users
- Radiation Safety Training for Sealed Source Users
- Radiation Safety Training for X-ray Machine Users

Refresher Radiation Safety Training

Refresher training is required by all personnel using radioactive materials every three years. Users of X-ray machines must complete refresher training each year.

Refresher training consists of repeating the appropriate online module available at Colorado.bioraft.com and scoring an 80% or above on the final quiz. BioRAFT reminds researchers of the need to complete refresher training based on the job activities selected for each user.

Personnel in laboratories which are inactive may still receive reminders to complete the training from BioRAFT. Contact the CU Radiation Safety Office regarding any issues with the radiation safety training modules available on the BioRAFT system.

Other Radiation Safety Training

While not required, a module covering laser safety is available on the BioRAFT system.

Other types of training sessions, including radiation safety training for Emergency Responders (such as EH&S personnel, CUPD, Boulder Fire) may be arranged by contacting the CU Radiation Safety Office.

Exposure Control

Dose Limits

The US NRC has established annual limits for the radiation dose individuals may receive. These limits were developed using international recommendations and risk estimates and they were set well below the level where biological effects from radiation exposure can be seen. Limits for children and members of the public (those who do not use radiation in their work, such as students walking through a laboratory to visit a professor) are significantly lower than those for laboratory researchers using radiation in their work. Safe work practices and following the ALARA philosophy will help reduce the doses received by anyone around the laboratory environment.

Individual (Radiation Worker)	Annual Dose Limit	
Whole Body (penetrating radiation)	50 mSv	(5,000 mrem)
Lens of the Eye	150 mSv	(15,000 mrem)
Skin and Extremities	500 mSv	(50,000 mrem)
Individual Organs (internal dose)	500 mSv	(50,000 mrem)
Embryo/Fetus (during gestation period)	5 mSv	(500 mrem)
Member of General Public	1 mSv	(100 mrem)
Minor (anyone under 18 years old)	1 mSv	(100 mrem)

Dose is a measurement of the radiation energy which is absorbed by tissue. It is important to remember that exposure to radiation does not automatically determine the dose received, because of mitigating factors such as:

- The energy and type of radiation emitted from the source;
- The amount of time spent near the radioactive source;
- The distance from the source; and
- Any shielding used by the individual.

Relative Risk

The use of radiation occupationally introduces a small amount of increased risk which should not be ignored. However, the amount of risk introduced by this radiation use is miniscule compared to other activities in which we engage in our everyday lives. It is important to keep the risk in perspective and balance the benefits of using radiation safety with the relative risk involved. The main concern with exposure to radiation in research and occupational pursuits is the possibility of inducing cancer.

How will radiation exposure increase the chance (risk) of cancer death?

The National Research Council established committees on the Biological Effects of Ionizing Radiations (BIER) to prepare a series of reports to advise the U. S. government on the health consequences of radiation exposures. One of these committees, BIER VII, published a report in 2006 titled *Health Risks from Radiation.* In this report, the BIER VII committee reaffirmed the findings from the BEIR V committee

(report published in 1990), which indicated that the risk of cancer death is 0.08% per rem for doses received rapidly (acute exposure). The risk from doses received over a long period of time (chronic exposure) might be as little as 0.04% per rem or 2-4 times lower. These risk estimates are averages considering gender, age groups, and various forms of cancer, so significant uncertainty is associated with the estimates. BEIR VII also noted that relatively high levels of radiation exposure increased the risk of heart disease and stroke but did not give specific risk estimates. The BIER VII committee stated that every exposure to radiation produces a corresponding increase in cancer risk (linear non-threshold, or stochastic, model). Most scientists believe that this is a conservative estimate or model of risk from low doses of radiation.

In the United States, the current death rate from cancer is approximately 20-25%, therefore out of any group of 10,000 United States citizens, about 2,000 will die of cancer. Although about 20% of the population will die from cancer, it is impossible to say which specific individuals will die or what specifically caused the formation of cancer.

Based on these assumptions, in a population of 10,000 people exposed to one rem (per person to the whole body), approximately eight additional deaths (0.0008*10,000*1 rem) would be due to the radiation exposure. So, instead of the 2,000 people expected to die from cancer naturally, now there are 2,008. This small increase in the expected number of deaths would not be seen in this group, due to natural fluctuations in the rate of cancer.

It is not certain that 8 people will die, but there is a risk of 8 additional deaths in a group of 10,000 people if they all receive one rem instantaneously (acute exposure). If the exposure is received over a long period of time (chronic exposure), the risk would be reduced to less than 4 additional expected fatal cancers.

Relative risk must be balanced with the benefit from the exposure to radiation. The risk is a small increase in developing fatal cancer. Risk comparisons show that exposure to radiation has a small risk relative to risks taken daily including driving a car, eating fatty foods, or smoking cigarettes. Some benefits from radiation include medical diagnosis and treatment, electricity, and results from scientific research.

Personnel Monitoring

One of the easiest ways to determine whether occupational exposure to radiation is as low as reasonably achievable is to monitor employees with instruments which measure radiation dose (dosimeters). For this reason, federal and state regulations require that individuals expected to receive more than 10% of the annual dose limits be monitored for occupational dose. At the University of Colorado, very few individuals are exposed to high enough levels of radiation to exceed this threshold. However, most researchers working in laboratories using radiation are monitored with a dosimeter to maintain a permanent record of any external dose received. Control dosimeters are used to remove exposure from background radiation from the recorded dose to individuals. Some uses of radiation are better measured

using different dosimetry techniques, including extremity monitoring and bioassay (measurement of internal radiation dose). Individuals working with volatile or large quantities of unsealed radioactive material may be required to undergo *in vivo* or bioassay measurements to assess the intake of radioactive material and determine the corresponding radiation dose. Thyroid bioassays are performed on workers handling larger activities of unbound radioiodine (such as sodium iodide), and urine bioassays are performed on workers handling high activities of beta emitters. In addition, bioassays may be performed as part of the response to spills or accidental releases.

Doses received from occupational radiation exposure are recorded in units of mrem, and records of doses received are stored securely at the CU Radiation Safety Office.

Dosimetry

Dosimeters are issued after proper radiation safety training has been recorded and a completed dosimetry application is received by CU Radiation Safety Office. The CU Radiation Safety Office is required to request exposure histories from all institutions at which individuals have recently worked to build an exposure history for the calendar year, ensuring annual limits are not exceeded.

It is the responsibility of the radiation licensee to ensure that dosimeters are worn and stored appropriately within their laboratory. If a dosimeter is no longer needed, it may be canceled by returning the dosimeter along with its holder to the CU Radiation Safety Office with a note indicating cancellation is needed.

Rotation students and other personnel changing laboratories should take their dosimeter with them to the new lab if radiation will be used and contact the CU Radiation Safety Office to track the new location. If radiation will not be used in the new lab, the researcher should return the badge and holder for cancelation.

Whole-Body Dosimeters

In general, individuals working in laboratories which use radiation of any type should apply for a whole-body dosimeter. The CU Radiation Safety Office may decide not to issue a dosimeter or to cancel a dosimeter in certain situations, such as:

- Use of only low-energy beta emitters ^{3}H or ^{14}C
- Use of only alpha-emitting radioisotope
- Use of <250 uCi maximum of low-energy beta emitters such as ^{35}S or ^{33}P
- Use of <100 uCi maximum of ^{125}I in RIA kits.
- Use of <100 uCi maximum of any radioisotope in a sealed source, except neutron-emitters
- Use of only sealed sources enclosed in an Electron Capture Detector or Liquid Scintillation Counter
- Use of an enclosed and interlocked x-ray system if surveys indicate no leakage above regulatory levels and all personnel dosimeters show < 100 mrem received in a six-month period of time.

Please note that alpha and low-energy beta radiation will not be detected by dosimeters and therefore, dosimeters are not issued to individuals using only alpha or low energy beta emitting nuclides. These types of radiation are not penetrating and do not contribute to whole body or deep dose equivalents.

Dosimeters are issued for a two-month wear period. At the end of the wear period, replacement dosimeters will be distributed through the designated badge coordinator/laboratory dosimetry contact. Dosimeters need to be returned in a timely manner to avoid false positive results in processing. Dosimeter holders are reused and are not to be returned with the used dosimeter unless it needs to be cancelled.

Whole body dosimeters are designed to measure whole body dose to penetrating (x- and gamma ray) radiation as well as beta particle radiation. Consequently, the badge should be worn on the portion of the body most likely to receive the highest dose, usually on the front of the chest, anywhere between the neck and the waist. Care should be taken to prevent contamination of the badge. If contamination occurs, the badge should be immediately returned to the CU Radiation Safety Office and a replacement will be issued for the remainder of the monitoring period. All dosimeters are assigned to specific individuals and are not transferable.

Extremity Dosimeters

Extremity dosimeters, also called a "ring badge" or "TLD ring," are designed to measure radiation dose to extremities – generally hands. They should be worn on the hand most likely to receive a dose. Multiple sizes are available. The labeled section on the ring should be closest to the radiation source, facing into the palm.

Those individuals using 1 mCi (37 MBq) or more of ^{32}P or other high-energy beta- or gamma-emitting radionuclides should be monitored with an extremity dosimeter. Individuals performing beam alignments on x-ray machines should also be monitored with an extremity ring.

Extremity monitoring rings may be requested by individual researchers or issued at the discretion of the Radiation Safety Officer (RSO), following an evaluation of experimental protocol.

Area Monitors

Some experimental set-ups may be best monitored using dosimeters which are affixed to a wall or other surface. These dosimeters do not substitute for personnel whole-body dosimeters. Area monitors are exchanged with the same frequency and process as the personnel monitors in a laboratory.

Radiation Exposure Reports

Written reports are issued by the dosimeter vendor, listing each individual and the exposure recorded. These reports are kept by the CU Radiation Safety Office for review and inspection by regulatory agencies. Any person receiving more than 50 mrem in one monitoring period is sent a written report. All employees have the right to know their measured radiation exposure at any time. Each monitored

individual is issued an annual report of exposures. Exposure reports can be requested at any time by contacting the CU Radiation Safety Office.

Lost or Damaged Dosimeters

If your dosimeter is damaged or lost, promptly contact your laboratory dosimetry contact or the CU Radiation Safety Office so that a replacement dosimeter can be issued.

Pregnancy and Fetal Dosimeters

Pregnant workers may voluntarily complete a fetal dosimeter application and fall under the lower dose limit allowed for the gestational period. If the pregnancy is not officially "declared" in writing, the woman will continue working under the higher radiation worker dose limit. If desired, a pregnant worker may request a second dosimeter to wear over the abdomen. Fetal dosimeters are exchanged monthly with written reports issued regardless of exposure level.

Where and How to Wear Your Dosimeter

Whole body dosimeters should be worn on the front of the body, in the area of the main torso, anywhere from waist to neck. Individuals who wear lead aprons should position the whole- body dosimeter at the collar level, outside of any lead protection. Extremity dosimeters should be worn on the hand most likely to be exposed, that is, the hand the closest to the sources of radiation. The white TLD area housing the TLD chip should face the inside of the hand.

Dosimeter Guidelines

- Dosimeters do not protect you from radiation exposure. They merely provide a record of personnel radiation exposure and identify possible problem areas on a continuing basis.
- Dosimeters do not change color or give any other indication regarding radiation exposure levels until returned to the vendor for processing.
- When not wearing a dosimeter, it should be stored in a low-background area away from any radiation sources.
- Dosimeters are issued to an individual. Do not lend your dosimeter to another person, and do not wear another person's dosimeter.
- Do not wear your dosimeter for any personal medical procedures involving diagnostic x-rays or nuclear medicine isotopes.
- Leave your dosimeter at work or in the laboratory, not in your car where it may be damaged by excessive heat or at home where it cannot measure your occupational radiation exposure.

Bioassay

Some radionuclides used at the University of Colorado present an increased risk of internal contamination. Use of higher activity levels of volatile radionuclides, such as unbound forms of radioiodine or beta emitters such as ^{3}H (tritium), requires *in vivo* or bioassay tests to monitor internal dose. Prior to beginning experiments which will require bioassays, researchers must submit to a baseline test to ensure accurate measurements following the experiment. If the experiments do not take place on

a regular schedule, baseline measurements may be required before each use of these materials. For continuous or regular experiments involving these materials, weekly or monthly bioassays may be scheduled with the CU Radiation Safety Office

All measured internal doses are included in dosimetry records for the affected individual. Internal exposures which exceed 10% of the annual dose limit may require follow-up, changes to experimental protocol and/or reporting to regulatory agencies.

Anyone planning to work with unbound radioiodine or large amounts of ^{3}H (tritium) should contact the CU Radiation Safety Office to schedule a baseline bioassay. Work with unbound radioiodine must take place at the CU Radiation Safety Office in a fume hood fitted with a charcoal and HEPA filter.

Follow-up bioassays are generally scheduled between one and seven days after the experiment, taking into account the biological half-life and anatomical target of the radionuclide involved.

Because most iodine in the body accumulates in the thyroid, internal contamination from radioiodine is measured by non-invasive gamma spectroscopy of radiation in the thyroid gland. The *in vivo* bioassay test requires about 10 minutes.

Tritium (^{3}H) replaces stable hydrogen in the body water of the researcher. A urine bioassay sample measured with a LSC is necessary to measure the amount of internal (^{3}H) contamination.

Mishaps and Emergencies

If an emergency involving radiation occurs, notify the CU Radiation Safety Office as soon as possible.

Emergency Contact Information

Boulder Campus (UCB)

Radiation Safety Office (Campus Hours)	(303) 492-6523
EH&S Department (Campus Hours)	(303) 492-6025
UCB Police Dispatch (After Campus Hours)	911 or (303) 492-6666

Colorado Springs Campus (UCCS)

UCB Radiation Safety Office (Campus Hours)	(303) 492-6523
Public Safety (After Campus Hours)	(719) 262-3111
UCCS Police Department (After Campus Hours)	9-911

Emergency Response to Mishaps and Emergencies

In the event of an emergency involving radiation, the CU Radiation Safety Office should be notified as soon as possible. If the emergency is life threatening, 911 should be contacted. Be sure to indicate that radiation is involved, particularly if there is a change the patient is contaminated.

Most likely, the police will contact CU Radiation Safety Office personnel if radiation or radioactive materials are involved. Please have the following information available for emergency personnel:

- **Your name** and the **name of the Principal Investigator** in charge of the laboratory
- Type of **radiation incident** (i.e., spill, x-ray malfunction, lost sealed source, etc.)
- The **location** of the incident
- Building
- Room number
- Location of a spill or machine within the laboratory
- A **phone number** where you can be reached, as well as the **location** where you will meet emergency personnel
- The **radionuclide** (or **energy** if an x-ray machine)
- The estimated **activity** involved
- The **volume** of liquid or solid involved
- The **chemical form** of the labeled compound

Unsealed Radioisotope Spills

Contamination in the Laboratory

In the event of a spill involving radioactive materials, immediately notify the other personnel in the immediate area of the spill. All personnel not involved in the spill should vacate the area, avoiding the spill area while leaving and being careful not to contaminate adjacent areas. If possible, survey shoes

before anyone leaves the area. Contact the CU Radiation Safety Office if assistance is needed to clean up the spill or if hazardous materials are involved.

How to clean up a small spill

- Wear proper PPE, including lab coat and disposable gloves. If the spill is on the floor, disposable booties may be useful. Be careful not to track contamination by walking around the lab or through hallways.
- Wear appropriate dosimetry and have a survey instrument nearby. Check hands and feet before moving to other areas.
- Dike around any loose liquid with absorbent material such as paper towels to prevent the spread of the contaminated area. Try to block access to any drains and prevent merging with any nearby hazardous materials.
- Pick up any solid items and place them in an appropriate radioactive waste container.
- Use a decontamination solution (such as RadiacWash or IsoClean) or a strong detergent to saturate the contaminated area. For some radionuclides, a survey meter may be helpful in narrowing down areas of contamination.
- Clean the area with paper towels, wiping from the outside to the inside to prevent further spreading contamination.
- Dispose of all clean-up materials in an appropriate radioactive waste container.
- Take wipe smears of the area to check decontamination progress. If more than twice background, repeat cleaning of area.
- Continue this process until the area is clean (less than twice background).
- Maintain all LSC printouts and record clean-up in laboratory survey logbook.
- Wash hands and re-survey shoes and labcoat/clothing before leaving.

Personnel Contamination

The CU Radiation Safety Office should be notified of any incidents involving direct exposure or radiation contamination on personnel. A dose assessment may need to be performed and/or regulatory agencies may need to be notified. The Radiation Safety Officer (RSO) will need to know how much radiation was involved, the radionuclide, and approximately how long the radiation was present on the skin and/or clothing.

Personnel Contamination Guidelines

- Contaminated skin should be washed thoroughly with soap and warm water. Do not scrub the area, as that could break the skin, increasing the chances of internal contamination. If necessary, emergency showers may be used.
- If the contamination involves a wound, flush the area to remove contamination and seek medical attention appropriate to the scope of the wound.
- Call 911 if the wound is life-threatening. If the bleeding is not severe, allow the wound to bleed as an aid in removing contamination.

- Contaminated clothing should be carefully removed and set aside in a plastic bag or on absorbent paper.
- Take a wipe smear survey of the skin to be sure it is clean. If it is twice background, repeat the cleaning process.
- Maintain all records, including LSC printouts, for review by the RSO.
- Notify the CU Radiation Safety Office as soon as possible.

Ingestion/Inhalation/Injection of Radioactive Materials

The CU Radiation Safety Office should be notified immediately of any ingestion, inhalation, or injection of radioactive materials.

- Inhalation of radioactive materials may be remedied somewhat by intentional coughing or deep-breathing in a clean area.
- Injection of radioactive materials can be helped somewhat by flushing the area thoroughly.

In some cases, bioassay tests may need to be performed to determine the amount of radiation ingested, inhaled, or injected. A follow-up with a medical provider may be necessary.

Leaking Sealed Sources

The CU Radiation Safety Office performs periodic tests on radioactive sealed sources to detect leaking or loss of integrity. If a sealed source is found to be leaking above regulatory levels, it will be taken out of service. Although rare, a sealed source may occasionally catastrophically lose integrity and release radioactive material. Leaking sealed sources can cause contamination hazards, as well as exposure hazards. If a sealed source appears to be leaking, use personal protective equipment and a survey instrument to check the area near the source for evidence of contamination. Contact the CU Radiation Safety Office for assistance with reducing the contamination hazard.

High Radiation Areas

Certain radiation uses on campus could result in possible exposure to high radiation levels. If an exposure to high levels of radiation has occurred or is suspected, contact the CU Radiation Safety Office immediately. A dose calculation may need to be performed and the RSO will need to know the duration of the exposure, the proximity to the radiation source, and the activity or energy of the source. Known high radiation areas will be posted as such.

Sealed Sources

Sealed sources are radioactive material which encased in an inert material, usually metal or plastic. Sealed sources may present an external exposure hazard but are not a significant contamination hazard under normal conditions. The basic principles of time, distance and shielding apply to the safe use of sealed sources.

Sealed sources are found in many different sizes and shapes. Some sources may contain alpha-, beta-, or gamma-emitting radioisotopes, or a combination of more than one. Sealed sources may be found in other equipment such as an Electron Capture Detector (ECD) attached to a Gas Chromatograph or inside a Liquid Scintillation Counter (LSC). They may also be inert metal onto which a thin film of radioactivity has been attached, known as plated sources. Metals or other materials which have been irradiated with neutrons, protons, or other particles, causing them to become "activated" may also be considered sealed sources. Sealed sources may have as little activity as a few Becquerels (fractions of a microcurie (uCi)) or much larger. They may be as small as a button, which can easily be lost, or contained in large devices.

Certain specific requirements are associated with the use of sealed sources, requiring the completion of Radiation Safety Training for Sealed Source Users before they may be used on campus. Depending on the radionuclide in the source, dosimetry may be required.

A radiation license is required for the possession and use of sealed sources at the University of Colorado. Depending on regulatory requirements, sealed sources are divided into different categories described below. Some sources must be checked for leakage of radiation at certain intervals and some must be inventoried so that their physical presence is noted at certain intervals. If a source is found to be missing, contact the CU Radiation Safety Office as soon as possible, as reports may need to be made to regulatory agencies.

Tier I Sealed Sources

As part of the University of Colorado Sealed Source Program, Tier I sources are defined as:

- Alpha-emitting sources with activities greater than 10 uCi (370 kBq) or
- Beta- or gamma-emitting sources with activities greater than 100 uCi (3.7 MBq)

These levels are set by federal and state regulations. Tier 1 sources must be checked for radiation leakage and the CU Radiation Safety Office performs leak-test surveys on all Tier I sources in accordance with regulatory requirements. Leak-testing must be performed every three months for alpha-emitting Tier I sources and every six months for beta- or gamma-emitting Tier I sources. The CU Radiation Safety Office notifies the radiation licensee if a Tier I source is found to be leaking above the regulatory limit of 0.005 µCi. Any source found to be leaking at this level must be removed from service for repair or disposal.

Tier II Sealed Sources

As part of the University of Colorado Sealed Source Program, Tier II sources are defined as sealed sources with activities below the Tier I amounts indicated above, though some radioactive materials do not have a

defined Tier II quantity in the regulations. The CU Radiation Safety Office inventories all Tier II sources every six months in accordance with regulations. If a source cannot be located during these checks, the radiation licensee will be notified and asked to locate the source.

Generally Licensed Devices

Generally Licensed Devices (GLDs) consist of a broad category of sealed sources such as:

- ^{63}Ni electron capture detectors (ECDs)
- ^{85}Kr aerosol neutralizers
- ^{210}Po static eliminators
- Sources internal to Liquid Scintillation Counters (LSCs)

A source can only be considered a GLD if it has a special GLD certificate from the manufacturer. Due to the nature of the Broad-scope Radioactive Materials License issued to the University by CDPHE, GLDs are leak tested and tracked similarly to other sealed sources at the University of Colorado. GLDs with activities greater than ten uCi (370 kBq) and beta- or gamma-emitting sources with activities greater than 100 uCi (3.7 MBq) are leak-tested according to the same frequency and process as Tier I sources. GLDs with activities less than the above are treated as Tier II sources. As with Tier I and Tier II sources, a radiation license is required before obtaining or using a GLD on campus. All GLDs must be received, disposed or returned to the manufacturer through the CU Radiation Safety Office.

Gas Chromatographs with Electron Capture Detectors

Some of the Gas Chromatographs (GCs) at the University of Colorado have Electron Capture Detectors (ECDs) which contain a sealed source, typically ^{63}Ni. These machines will usually have a radioactive materials sticker or label identifying the presence of the radioactive source. Flame Ionization Detectors (an alternative to an ECD on a GC) do not contain radioactive sources. Radiation Safety Training for Sealed Source Users is required before using these machines, but dosimetry is not necessary for normal operation of these devices.

Sealed Source Storage and Use

The CU Radiation Safety Office tracks sealed sources on campus and posts a Sealed Source Inventory on or near each storage location. The Sealed Source Inventory describes the sources stored in each location. Cabinets used to store sealed sources must be kept locked at all times when not actively in use. If a source is to be in use for an extended period of time and not under constant surveillance of a trained radiation user, arrangements must be made to secure the source against unauthorized use or removal.

If a sealed source is to be used at another location in the laboratory, it must be signed out on the Sealed Source Sign-out Log. This log is generally found near the cabinet where the source is stored and must be completed, regardless of location and duration of use. When the source is returned to storage, this should also be noted on the Sealed Source Sign-out Log. Use of the log assists in finding sources when inventory or leak-tests are required.

Contact the CU Radiation Safety Office if any source is to be moved to a location outside of the laboratory's authorized locations, as this may require an amendment to the radiation license. Proper accountability is essential for sealed sources. Contact the CU Radiation Safety Office to facilitate disposal of a sealed source or the return of a decayed source to the manufacturer, as is frequently required with GLDs.

Use of Sealed Sources at Field Locations

Occasionally, a collaborative research project may require the use of a sealed source at an off-campus field location. Whether in the same city or a completely different state or country, certain regulatory protocols must be arranged for off-campus use of radioactive materials. Contact the CU Radiation Safety Office as soon as possible to begin preparing for off-campus work, as the process may take some time. Some use locations may require filing of reciprocity paperwork with the US NRC which may not receive approval for weeks or months.

While at a field location, some sources can be transferred to the license of the institution in charge of the field location. In this case, regulatory requirements for leak-testing and inventorying of the source are the responsibility of the radiation safety staff at the field location. The RSC has required that any radiation licensee sending material to an off-campus field location provide an emergency contact number where they can be reached any time of day while the source is off-site.

The CU Radiation Safety Office will ship sealed sources to off-campus locations and must be consulted regarding the return of the source to campus. Sources returned to campus must be delivered to the CU Radiation Safety office for required regulatory testing before being returned to the laboratory.

Equipment with Internal Sealed Sources

Many laboratories use liquid scintillation counters (LSCs) to analyze wipe smears and other samples. Machines which calculate H# (efficiency) are likely to contain a sealed source, typically a gamma-emitter such as ^{137}Cs, ^{133}Ba or ^{226}Ra. These internal sources are managed in the same way as other sealed sources and must be removed from the machine prior to disposal. Contact the CU Radiation Safety Office for assistance with removal of the internal source and lead shielding prior to disposal of a LSC.

Gamma counters do not typically contain an internal source.

Calibration standards for LSCs must be managed through the CU Radiation Safety Office as sealed sources. These standards frequently contain hazardous liquid and can be costly to dispose. Laboratories are discouraged from keeping LSC calibration standards on hand, as the CU Radiation Safety Office has sets to use when calibrating instruments. Contact the CU Radiation Safety Office to arrange management and/or disposal of LSC calibration standards.

Portable Gauges and XRF Devices

Portable gauges and XRF devices not in storage must be leak tested regularly by the CU Radiation Safety Office. Because these instruments contain sealed sources, personnel working with them are required to

compete Radiation Safety Training for Sealed Source Users. When planning to obtain or use such a device, contact the CU Radiation Safety Office for information on licensing, using, and storing these items safely.

Disposal or Return of Sealed Sources to Manufacturer

Sealed sources require special provisions for disposal. Some sources may be returned to the manufacturer for reuse/recycling rather than disposed. Contact the CU Radiation Safety Office for assistance with disposal of any of sealed source or help returning a source to the manufacturer.

X-ray Machines

Laboratories wishing to order an x-ray machine should first obtain a license for the device from the RSC through the CU Radiation Safety Office. Radiation Safety Training for X-ray Machine Users is required for all personnel prior to beginning work with the machine. Depending on use, whole-body dosimeters and/or extremity monitors may be issued to personnel.

While management of x-ray machines is the responsibility of the radiation licensee authorized for the use of the machine, it is the responsibility of each member of the laboratory to maintain safe use of the x-ray machine(s) in their area.

Most of the X-ray machines used at the University of Colorado are required to be certified every two years by a Qualified Inspector (QI) certified by CDPHE. These certifications and additional radiation surveys following repairs or modifications are coordinated through the CU Radiation Safety Office. X-ray equipment new to campus needs to be registered with CDPHE through the CU Radiation Safety Office.

Purchasing X-ray Machines

Purchases of x-ray machines should be pre-approved by the CU Radiation Safety Office.

In general, arrangements may be made with the CU Radiation Safety Office to have X-ray machines delivered directly to the area of use. Following the initial set-up, the machine will need to be surveyed and certified within the first 90 days to comply with State regulations.

Analytical X-ray Systems

Analytical X-ray equipment is used for X-ray diffraction analysis, fluorescence analysis, or direct X-ray transmission analysis of materials. These analytical X-ray systems are comprised of components that utilize X-rays to determine elemental composition, or to examine the microstructure of materials. Analytical x-ray devices are regulated under Part 8 of the Colorado Rules and Regulations Pertaining to Radiation Control.

Analytical x-ray devices have the potential for significant radiation exposure to personnel and must be certified every two years by a Qualified Inspector. This certification can be arranged by contacting the CU Radiation Safety Office. Per the RSC, X-ray systems with open-beam configurations which are not equipped with a safety device are not allowed to be used on campus. Safety interlocks must be installed and fully functional whenever an analytical x-ray machine is in use.

Laboratories using analytical x-ray systems should post Emergency Procedures in a conspicuous location, along with the Notice to Employees required by State regulations.

Summary of CCR Part 8 Requirements

Equipment Requirements

- Each x-ray unit must have a safety device which prevents the entry of any portion of an individual's body into the primary x-ray beam path, or which causes the beam to be shut off upon entry into its path. This is also known as an interlock.
- The x-ray unit must have a readily discernible indication of x-ray tube "on-off" status; shutter "open-closed" status; and an easily visible warning light labeled with the words *X-RAY ON* or similar words.
- Any equipment installed after October 1, 1978, shall have fail-safe characteristics in the warning devices.
- Any unused ports shall be secured in the closed position, in a manner which will prevent casual opening.
- All analytical x-ray equipment shall be labeled with a readily discernible sign or signs bearing the radiation symbol and the words: *Caution High Intensity X-ray Beam* on the source housing; *Caution Radiation - This equipment produces Radiation When Energized* near any switch that energizes an x-ray tube; or *Caution Radioactive Material* if the radiation source is a radionuclide.
- Any x-ray unit installed after October 1, 1978, shall be equipped with a shutter for each port on the radiation source housing that cannot be opened unless a collimator or a coupling has been connected to the port.
- Each source housing shall be equipped with an interlock that shuts off the tube if it is removed from the radiation source housing, or if the housing is disassembled.
- Each radioactive source housing, or port cover or each x-ray tube housing shall be constructed so that, with all shutters closed, the radiation measured at a distance of 5 cm from its surface is not capable of producing a dose in excess of 2.5 mrem (0.025 mSv) in one hour. For systems utilizing x-ray tubes, this limit shall be met at any specified tube rating. These requirements should be met by the manufacturer. Contact the CU Radiation Safety Office for assistance with these surveys.
- Each x-ray generator shall be supplied with a protective generator cabinet which limits leakage radiation measured at a distance of 5 cm from its surface such that it is not capable of producing a dose in excess of 0.25 mrem (2.5 mSv) in one hour.

Area Requirements

The local components of an analytical x-ray system shall be arranged such that no radiation levels exist in any surrounding local area which could result in a dose to an individual in excess of the public dose limits of 100 mrem (1 mSv) per year and 2 mrem (0.02 mSv) in any one hour. These dose limits may be met by arrangement/location of components, adding shielding or controlling access.

Each area or room containing analytical x-ray equipment shall be conspicuously posted with a sign or signs bearing the radiation symbol and the words *Caution X-Ray Equipment*. Each area should also have *Emergency Notification* signs which include telephone numbers for the radiation licensee as well as other emergency contact designee(s). These signs may be obtained from the CU Radiation Safety Office or from laboratory safety supply vendors.

Radiation surveys shall be performed:

- upon installation of the equipment and at least once every 12 months thereafter
- following any change in the initial arrangement, number or type of local components in the system
- following any maintenance requiring the disassembly or removal of a local component in the system
- during the performance of maintenance and alignment procedures if the procedures require the presence of a primary x-ray beam when any local component of the system is disassembled or removed
- any time a visual inspection of the local components in the system reveals an abnormal condition; and
- whenever personnel monitoring devices show a significant increase over the previous monitoring period or the readings approach the occupational dose limits for radiation workers.

Operating Requirements

Normal operating procedures shall be written and available to all analytical x-ray equipment workers. No individual shall be permitted to operate analytical x-ray equipment in any manner other than that specified in the procedures unless such individual has obtained the written approval of the RSO.

No individual shall bypass a safety device or interlock, unless such individual has obtained the written approval of the RSO. Such approval shall be for a specified period of time and must be performed under the supervision of the radiation licensee. When a safety device or interlock has been bypassed, a readily discernible sign bearing the words *Safety Device Not Working*, or similar words, shall be placed on the radiation source housing.

Except as described in the previous paragraph, no operation involving removal of covers, shielding materials or tube housings, or modifications to shutters, collimators, or beam stops shall be performed without ascertaining that the tube is off and will remain off until safe conditions have been restored. The main switch, rather than interlocks, shall be used for routine shutdown in preparation for repairs.

If the x-ray device contains a radioactive source, then replacement, leak testing, or other maintenance or repair procedures shall be conducted only by individuals specifically authorized under the University Radioactive Materials License. For information contact the CU Radiation Safety Office.

Personnel Requirements

Individuals must complete Radiation Safety Training for X-ray Machine Users through the CU Radiation Safety Office and receive on-the-job training in the laboratory prior to operating or maintaining analytical x-ray equipment. This training should include identification of radiation hazards associated with the use of the equipment; significance of various radiation warnings, safety devices and interlocks incorporated into the equipment; proper operating procedures for the equipment; recognition of symptoms of an acute localized exposure; and proper procedures for reporting an actual or suspected exposure.

Personnel dosimeters issued by the CU Radiation Safety Office shall be worn by analytical x-ray equipment users as required by the RSO. Personnel maintaining analytical x-ray equipment if the maintenance procedures require the presence of a primary x-ray beam when any local component in the

analytical x-ray system is disassembled or removed will be issued an extremity dosimeter to monitor dose to the hands.

Medical (Healing Arts) X-ray Systems

Medical x-ray devices (healing arts or veterinary medicine) are regulated under Part 6 of the Colorado Rules and Regulations Pertaining to Radiation Control. X-ray devices operated for medical (diagnostic/therapeutic) purposes must be licensed by the Medical Licensing Board of the State of Colorado. These devices must be inspected every year by a Qualified Inspector with specific qualifications for medical devices. The CU Radiation Safety Office should be contacted for more information regarding licensing and certification of x-ray machines used in the healing arts.

Just because an x-ray machine is used with humans does not mean it falls under medical (or healing-arts) regulations. The difference has to do with the use of the machine to perform diagnostic or therapeutic treatments. Certain human-use machines, such as DXA units used as part of a research study, may not require the higher level of licensing. Contact the CU Radiation Safety Office to discuss the specific planned use of a proposed x-ray unit.

Security and Storage of X-ray Machines

Each radiation licensee must ensure that x-ray machines under their authorization are kept secure from unauthorized removal or operation. The easiest way to assure this security is by locking laboratory doors when no one is present and/or locking the device when left unsupervised. Operating keys should not be kept in the machine when not actively in use.

All laboratory areas in which x-ray machines are used should have a sign displayed on all entrances warning of the presence of the x-ray hazard. The CU Radiation Safety Office may supply appropriate signs and stickers, or they can be ordered from laboratory supply vendors.

Transfers of X-ray Machines

X-ray machines may be transferred to another licensed laboratory with prior approval from the CU Radiation Safety Office. A new or amended radiation license may need to be approved by the RSC prior to the transfer. X-ray machines transferred to long-term storage need to be updated with the CDPHE X-ray Certification Unit through the CU Radiation Safety Office. Storage facilities must be kept secure, so the machine cannot be accessed or removed without the permission of the radiation licensee or RSO.

Disposal of X-ray Machines

Radiation-producing machines should have the x-ray tube removed and/or destroyed prior to disposal. All radioactive signs and symbols must be obliterated or removed. Contact the CU Radiation Safety Office to notify of any x-ray machine disposal so that the proper forms may be filed with the CDPHE X-ray Certification Unit.