CHAPTER 9 LABORATORY PROCEDURES

1.0 RADIATION SAFETY TRAINING

1.1 Radiation Worker Training

All individuals who work with radioactive materials at the University are considered to be Radiation Workers (Radworkers). Individuals who routinely occupy or frequently work in locations where radioactive materials are used or stored may also be considered Radworkers. All Radworkers must receive documented training in radiation safety. A standard form for use in recording Radworker training is available from Radiation Safety. It is the responsibility of the Authorized User to ensure that this training has been completed. Radworker training should be completed prior to the performance of any tasks using radioactive materials or involving radiation exposure. The minimum requirements for Radworker training shall include:

- Reading applicable portions of this Manual.
- General rules of radiation safety.
- Specific rules for the authorized uses and use locations.
- Directions for contacting the Radiation Safety Officer and Radiation Safety Staff for assistance.
- Directions for notifying the proper authorities in the event of an emergency or accident.

1.2 Advanced Radiation Worker Training

The Authorized User is required to have at least one worker in the authorized use location certified as an Advanced Radiation Worker by successful completion of training approved by Radiation Safety. A period of 90 days will normally be allowed to complete this training requirement. Any individual who is certified as an Advanced Radworker is considered to have met all Radworker training requirements. Advanced Radworkers should provide direct guidance to Radworkers in the performance of radiological work activities.

1.3 Visitors, Members of the Public, and Maintenance Personnel

Visitors, members of the public, and maintenance personnel should not be allowed access to radioactive materials or radiation sources. However, if such personnel should have a justifiable need to perform tasks associated with, or in the vicinity of radioactive materials, they must be adequately protected and informed of the radiation hazards. Radiation exposure to non-Radworker personnel must be kept to minimal levels (<100 mrem/year from all licensed sources). In most cases, direct and continuous guidance should be provided for such activities by a trained Radworker. If this is not practical, appropriate measures must be taken to control access to radiation hazards or radioactive materials, or to perform radiological surveys and release locations or components to unrestricted use.

2.0 RADIOLOGICAL WORK PLANNING

- Plan the layout of the laboratory in relation to your radiological work. When practical, locate all radiological use and storage areas in the same part of your laboratory. The exception to this is to allow adequate distance from radiation sources to reduce personnel exposure.
- Use the smallest reasonable quantity of radioactive material for the desired purpose.
- When a choice of radionuclides is available, use the least hazardous radioisotope for the planned experiment.
- Do not order more radioactive material than needed for the anticipated use. Handling of excess material may increase personnel exposure. Also, regardless of half-life, all compounds containing radioactivity undergo decomposition as a result of radiation effects.
- Prior to the individual performance of a first time operation, practice the task with inert (non-radiological and non-hazardous) materials. This is especially important for delicate operations or when working with larger than normal quantities or concentrations of radioisotopes.
- Verify that all needed equipment, instrumentation, and supplies are available and operational prior to beginning radiological work.

3.0 RADIOACTIVE MATERIALS SECURITY

Federal and state regulations require that radioactive material be kept secure from unauthorized access. This requirement applies to all licensed (non-exempt) radioactive materials. See Chapter 7 of this manual, *Radiological Postings* for additional information about exempt radioactive materials. You may meet this security requirement by using one or more of the following options:

- keep the doors locked for all rooms where radioactive materials are located,
- keep all radioactive materials (including waste) in locked enclosures, and/or;
- ensure that all radioactive materials are continuously controlled by individuals with training in radiation safety who are willing to challenge other personnel who might be attempting unauthorized access.

Radioactive material in the form of small quantity sealed sources that are an integral part of a non-portable piece of equipment (i.e. liquid scintillation counters and gas chromatographs) are considered secure from unauthorized access when the equipment is located in an authorized use location.

Note: Any lost or missing radioactive materials must be reported to Radiation Safety immediately.

4.0 ENGINEERING CONTROLS

Engineering controls are the physical equipment and mechanical devices used for control of radiological hazards. Engineering controls facilitate the safe performance of radiological work and can reduce the need for restrictive personnel protective equipment.

1) Radioactive materials that are handled or used in unsealed forms should be confined to control the release of materials and to prevent the spread of contamination.

2) Use trays and/or absorbent surface covers (secondary containment) to catch and retain spilled materials in all appropriate radioisotope work locations.

3) Plastic bags may be used for temporary storage of lab ware or associated contaminated items. The bags should be labeled and only used for short periods of time until the potentially contaminated items are surveyed "clean" of contamination, decontaminated, or held for radioactive decay.

4) Use secondary containment devices for any bulk storage of liquid radioisotopes. This should include the use of trays or bins under your liquid waste carboys to contain spills or leakage.

5) The use of an approved fume hood is required for any activity likely to generate dust, fumes or vapors containing radioactive materials.

6) Fume hoods should be used when working with volatile radioactive materials, and when initially opening vials containing milliCi quantities of radioisotopes.

7) Use radiation shielding when working with gamma or high energy beta emitting radioisotopes to keep dose rates ALARA.

8) Store radioisotopes in the original shipping container, or in a container that provides equivalent or better radiation shielding than the original shipping container.

9) Survey radioactive material use, storage, and waste container locations for radiation dose rates, as described in Chapter 6, *Radiological Surveys*. If significant radiation levels are found at 1 foot from the source, use shielding to lower the work area radiation levels. Contact Radiation Safety for assistance if necessary.

10) High energy beta emitting isotopes such as P-32 should be shielded with low density materials such a plastic, Plexiglas, or Lucite. This type of shielding is commercially available through lab safety suppliers. Also, custom made shapes and shielding devices can be constructed on campus by the UGA Research Services Instrument Shop.

11) Gamma emitting isotopes (I-131, Cr-51, Fe-59, etc.) are best shielded with dense materials such as lead bricks, blocks, or sheets. Surplus lead shielding materials are sometimes available on campus, contact Radiation Safety for details. However, use caution when handling or working with lead. Lead (Pb) is considered a hazardous material due to risks of inhalation, ingestion, or absorption of this heavy metal into the body.

12) Use remote handling tools in the form of work stands, tongs, tweezers, etc. to reduce exposure to the extremities (hands & fingers) and whole body when appropriate.

5.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Personal protective equipment is clothing and equipment that is worn for the purpose of reducing exposure to workplace hazards.

1) Lab coats and disposable gloves are considered the minimum acceptable PPE for use by personnel handling unsealed radioactive materials.

2) Appropriate footwear with a closed toe (no sandals) must be worn when working with radioactive materials that have the potential to be spilled on the foot.

3) If PPE is required for both radiological and laboratory safety purposes, the PPE that provides the greatest protection should be used.

4) The use of double gloves (two pair) is encouraged and should be considered mandatory when working with isotopes that can be absorbed through the skin (i.e. tritiated water, radioiodine).

5) Eye protection in the form of safety glasses or face shields should be used by persons performing operations with the potential for liquid splash, or during the conduct of procedures that might otherwise result in contamination of the eye.

6) Eye protection is also required when handling P-32 (or other high energy beta emitters) in individual quantities >1 millicurie to reduce the amount of Beta radiation that reaches the eye.

7) Radiological use PPE should not be worn outside of a posted radioactive materials area or radiological use laboratory. When transporting radioactive materials outside of posted areas, the radioactive materials should be packaged or contained in a manner such that no PPE is necessary.

8) Gloves should be monitored periodically during work with radioisotopes. Contaminated gloves should be promptly removed. After removal of contaminated gloves, monitor the inner pair of gloves (or skin surface, if only 1 pair is used) for contamination. If skin or personal clothing contamination is detected, take appropriate actions as described in Chapter 8, *Response to Radiological Incidents*.

9) Lab coats should be scanned for contamination at a minimum frequency of monthly, at any time contamination is suspected, and prior to laundering. The ends of the sleeves, front of the lab coat, and pockets are likely locations for contamination to be present. If contamination is detected on a lab coat due to short lived radioisotopes, it may be bagged, labeled, and stored for decay. If the contamination is due to long lived radioisotopes, contact Radiation Safety for recommendations on decontamination. A replacement lab coat should be used until radiological surveys indicate no detectable activity on the previously contaminated lab coat.

10) The exemptions to personnel contamination monitoring detailed in section 6.0 below also apply to monitoring of PPE described in this section.

6.0 PERSONNEL CONTAMINATION MONITORING

Personnel contamination monitoring is the only practical method to ensure that your skin or personal clothing is not contaminated with radioactive material. Neglecting to perform monitoring can result in the spread of contamination and increases the risk of inhalation, ingestion, or absorption of radioactive material. Personnel contamination monitoring is commonly referred to as “frisking” in the field of radiation protection.

The following requirements apply to personnel contamination monitoring.

1) Personnel contamination monitoring is required prior to exiting a radiological use laboratory after handling unsealed radioactive materials.

2) Personnel contamination monitoring should be performed upon the completion of any single operation involving the handling of unsealed radioactive materials.

3) The minimum standard for personnel contamination monitoring consists of a slow scan with the probe of a portable monitoring instrument, checking the hands, shoes, and any other areas of the body or clothing with the potential to have become contaminated during the operation conducted.

4) After a spill or unplanned contamination event, a “whole body frisk” should be performed. A whole body frisk is a scan of the entire body/clothing for contamination. When properly performed, a whole body frisk takes two to three minutes.

5) The “hand & foot frisk” involves a scan of the palms, fingers, and thumbs of both hands and the soles of the shoes. This simple task greatly reduces the risk of inhalation or ingestion of radioactive material and ensures that if contamination is present on floors it is not spread to normally “clean” areas.

6) Perform personnel contamination monitoring in a low background area with the instrument on the lowest scale. A background level <0.05 mR/hr is recommended.

7) Notify the AU, Advanced Radworker, and Radiation Safety of any instances of skin or personal clothing contamination.

8) For additional information about personnel contamination monitoring and response to personnel contamination events, see Chapter 8, *Response to Radiological Incidents*.

9) This requirement for personnel contamination monitoring does not apply to laboratories using exclusively H-3 or that are exempted from having a portable monitoring instrument in accordance with Chapter 4, *Facilities and Equipment Considerations.*

7.0 PERSONNEL DOSIMETRY

7.1 Dosimetry Requirements

1) Radiation monitoring dosimetry is required for all individuals working with gamma and high energy beta emitting isotopes (P-32, I-125, I-131, Na-22, Tc-99m, Cr-51, etc.) except as noted below.

2) Radiation Workers without dosimetry may perform limited tasks approved and supervised by an AU or Advanced Radiation Worker. Individuals without dosimetry should not be exposed to dose rates ≥2 mR/hr or allowed to frequent areas with dose rates ≥ 0.2 mR/hr. These radiation exposure levels are for whole body dose rates as measured at 30 cm (approximately 1 foot) from the radiation source.

3) Extremity monitoring (finger rings) is required for all individuals performing operations that involve handling individual quantities ≥1 milliCi of P-32 or other gamma and high energy beta emitting isotopes.

4) Dosimetry is not required for personnel working in laboratories permitted only for milliCi quantities of isotopes which emit primarily beta radiation with energies below 250 keV (H-3, C-14, S-35, and P-33). The exclusive use of I-125 immunoassay kits with < 25 µCi per kit is also exempted.

5) Laboratories where only small quantities (i.e. ≤250 µCi) of gamma and high energy beta emitting isotopes are handled during single operations, or where radioisotopes are used infrequently need not have all individuals working with the radioisotopes monitored with dosimetry. In these cases, and as otherwise approved by the Radiation Safety staff, only a representative individual(s) responsible for performing the majority of the radiological work should be monitored.

6) Dosimetry may be discontinued for individual workers on a case by case basis if historical data indicates that exposures are consistently minimal. This determination will be made by the Radiation Safety staff.

7.2 Procurement and Control of Dosimetry

1) When it has been determined that dosimetry is needed, the individual to be monitored must submit a *Dosimetry Request Form* (or RSO approved equivalent) to Radiation Safety. Allow a minimum of 2 weeks for the processing of a new request for dosimetry.

2) Individuals who have had prior occupational radiation exposure at other institutions will need to complete an *Individual Radiation Exposure History Data Sheet* (or RSO approved equivalent) in order to be badged.

3) When not in use, dosimetry badges should be stored in a low background area. A designated location for dosimetry badge storage is recommended.

4) Take care not to contaminate dosimetry badges. If you suspect your badge may be contaminated, promptly notify Radiation Safety.

5) Immediately report lost, misplaced, or damaged dosimetry to Radiation Safety. An investigation in support of a radiation exposure estimate must be initiated for lost dosimetry.

6) Radiation monitoring dosimetry is used to determine a legal record of individual radiation exposure received at the University. Never tamper with a badge or wear anyone else's dosimetry.

7) Do not use your UGA dosimetry when traveling to other institutions without the approval of the RSO or designee. Also, do not wear your dosimetry when away from UGA facilities or during any personal medical care.

8) Dosimetry badges are typically changed out on a monthly or quarterly cycle. Turn in dosimetry badges to the designated badge coordinator for your work location at the assigned time. If you are terminating work with radioactive materials at UGA, you are responsible for returning your dosimetry badge to Radiation Safety in order to ensure that your radiation exposure is properly measured and recorded.

7.3 Radiation Exposure Reports

- Individual radiation exposure reports will be distributed to monitored personnel on an annual basis.
- Individual radiation exposure reports may be requested from Radiation Safety at any time. Requests should be submitted in writing and include the signature of the monitored individual due to the privacy issues associated with radiation exposure reports.
- Radiation exposure report summaries may be provided to Authorized Users or supervisory personnel as a part of the ALARA program. Personal information that is inappropriate for distribution (dates of birth, social security numbers) will be omitted or defaced on these reports. However, the data contained in these summary reports should still be considered confidential with respect to individual privacy.

8.0 RADIATION SAFETY RECORDS

Records in support of the requirements described in this Radiation Safety Manual must be maintained in the laboratory. These records must be available for review by the Radiation Safety staff or regulatory agencies. Unless otherwise specified, it is recommended that records be organized in labeled binders for easy access and to facilitate the review process. Examples of these records include:

- radioactive materials permit application or initial radioactive materials license application
- radioactive materials permit or initial radioactive materials use approval

- radioactive materials permit sign-in sheets (new style permits only)
- radioactive materials permit amendments
- monthly radiological survey records
- sewer disposal records
- radioactive materials inventory summary sheets
- inventory of radioisotopes forms
- training records

9.0 SAFE RADIOLOGICAL WORK PRACTICES

1) No eating, drinking, smoking, applying cosmetics, or handling of contact lenses should be performed in a radiological use laboratory or posted radioactive materials area.
2) Do not store food, drink, or use/store items for the preparation of food or drink in radiological use areas.
3) Radioactive material areas posted exclusively for the presence of sealed sources may be exempt from the two requirements listed above, if specifically approved by the RSO or designee.
4) Please be aware that the presence of empty food or drink containers in radioactive material areas may be regarded as evidence of consumption of these products by personnel performing laboratory inspections (either the UGA Radiation Safety staff or representatives of regulatory agencies).
5) Do not work with unsealed radioactive materials if you have any cuts or breaks in the skin with the potential to result in internal contamination. Never pipette by mouth. Avoid all activities that are likely to result in the ingestion, inhalation, or absorption of radioactive materials.
6) Store radioactive materials in clearly labeled containers. Labels should include the isotope, quantity, and date.
7) Notify the RSO if you have recently had, or are scheduled to have, any medical treatment involving the internal administration of radioactive materials (not X-rays). Individuals who have recently had a medical internal administration of radioactive materials can have incorrect (excessive) exposure recorded on personnel dosimetry and difficulty in monitoring for radiation or contamination.
8) Laboratory workers shall not initiate any changes to experimental procedures using radioactive materials without prior approval of the Authorized User or designee. Also, any abnormal occurrences in radiological use locations should be promptly reported to the AU or designee. If the AU is not available, the Environmental Safety Division may be contacted for assistance.
9) Radioactive materials are only to be used or stored in authorized use locations. Changes to authorized use locations must be processed through the permit amendment process.
10) Radioactive waste must be properly packaged, labeled, and controlled. See Chapter 10, *Radioactive Waste Handling and Disposal* for additional information.
11) Perform routine and non-routine radiation and contamination surveys at a frequency adequate to ensure that personnel exposure is **ALARA**. See Chapter 6, *Radiological Surveys* for additional information.
12) During radiological work, a portable monitoring instrument should be turned on and near the work location. When working in a fume hood, the instrument should be in an easily accessible

location outside the hood. This requirement does not apply for laboratories exempted from monitoring as described in section 6 of this chapter.

13) Potentially contaminated laboratory equipment must be surveyed and determined to be free of contamination in accordance with the requirements of Chapter 6, *Radiological Surveys* prior to removal from a radioactive materials area.

10.0 SPECIFIC RADIOLOGICAL HAZARDS

10.1 Internal Hazards

Contamination occurs when an unsealed radioactive material (liquid or dispersible solid) is in an undesirable location. The primary hazard of contamination is inhalation, ingestion, or absorption of radioactive material into the body. All dispersible radioactive materials may cause contamination and are therefore considered internal hazards. Internal hazards are controlled by surveys and monitoring, engineering controls, and personal protective equipment (PPE).

10.2 External Hazards

Radiation is energy, in the form of particles or waves, emitted from radioactive materials. An external radiation hazard occurs only when the amount of radiation emitted is powerful enough to reach and interact with the human body. External hazards are controlled by the principles of time, distance, and shielding.

1) **Time**

Less time exposed equals less total exposure. For example, a person in a radiation area for 1 hour where the dose rate is 10 mrem/hr will receive a radiation exposure of 10 mrem. If the time spent in the radiation area was reduced to 30 minutes, the individual exposure would be reduced to 5 mrem.

2) **Distance**

If you double the distance from a radiation source your exposure is reduced by a factor of four (inverse square law).

3) **Shielding**

Increasing the amount of appropriate shielding also reduces the dose rate from a radiation source. Shielding can be in the form of specifically designed materials as discussed in other parts of this manual. Also, commonly available laboratory materials such as the sash of a fume hood, glassware, water, and shipping containers provide some degree of shielding.

10.3 Radioactive Iodine

1) Radioactive iodine (I-125, I-131) is both an internal and external hazard.
2) I-125 has a radiological half-life of 59.7 days. I-131 has a radiological half-life of 8.04 days.
3) Radioactive iodine in an unbound state may readily become airborne, resulting in an inhalation hazard. It may also be absorbed into the body via direct contact with the skin. Once inside the human body, radioactive iodine will concentrate in the thyroid gland.

4) The most volatile forms are sodium iodide (NaI) and radioiodine in acidic solutions.

5) Training for users of radioactive iodine should include observing Radworkers experienced in radioiodine procedures, practicing procedures with non-radioactive materials, and demonstrating proper work practices to an experienced radioiodine worker prior to un-supervised performance.

6) Double disposable gloves (wear 2 pair) are required for radioiodine work.

7) Only small quantities of radioiodine may be handled on an open bench, such as RIA kits that contain $\leq$ 25 microcuries. See section 4.1 of Chapter 3 for additional information about fume hood requirements.

8) Use syringes and needle guides for removal of radioiodine through the septum of shipment vials. Charcoal traps are also available. Follow the vendor's instructions for the use of these products. If the package insert instructions are not available, refer to vendor catalogs, websites, or call the vendor by telephone for technical information.

9) Containers of radioactive iodine must be kept tightly sealed at all times to prevent airborne radioactivity. Ziploc style plastic bags should be used to contain small contaminated items. Remember to seal and label the bags.

10) Fume hoods should be used to reduce the risk of inhalation. The sash of the hood should be kept at the lowest practical level during work.

11) Monitoring must be performed at frequent intervals to detect and prevent the spread of contamination. A conventional GM probe is very inefficient for the detection of I-125, which emits low energy radiation (electron capture X-rays). A scintillation detector designed for detecting I-125 is the best choice of detector for a portable monitoring instrument. I-131 emits a combination of beta and gamma radiation and is easily detected with portable instruments equipped with conventional GM detectors.

12) Contamination surveys should include wipe tests analyzed by liquid scintillation counting or by use of a low energy gamma counter.

13) In addition to contamination surveys, radiation dose rate surveys should be performed in radioiodine laboratories, except for laboratories where only small quantity RIA kits are used. Radiation dose rates should be measured at 1 foot from use areas, storage locations, and waste containers as described in Chapter 6, *Radiological Surveys.*

14) Individuals working with radioactive iodine must have thyroid bioassays in accordance with the requirements of Chapter 3, *Radiation Exposure Limits*. Notify the Radiation Safety staff to schedule a thyroid bioassay.

15) Any individual who has had skin contamination due to radioactive iodine or has reason to suspect that they may have inhaled, ingested, or absorbed radioiodine should promptly notify the Radiation Safety staff to schedule a thyroid bioassay.

10.4 Phosphorus-32

1) Phosphorus-32 (P-32) is primarily an external hazard, but it is also an internal hazard. P-32 decays by the emission of a high energy beta particle. This intense beta radiation has the potential to result in very significant personnel exposure, especially to the skin and extremities (hands or fingers). The lens of the eye should also be protected from beta radiation by the use of safety glasses or other protective measures.

2) P-32 has a radiological half-life of 14.3 days.

3) Extremity dosimetry (ring badge) is required for persons performing direct handling of P-32 in individual quantities $\geq$1 millicurie.

4) P-32 should never be directly shielded with dense materials such as lead, due to the Bremsstrahlung effect. Bremsstrahlung radiation is the production of X-rays as a result of charged particle interaction with a dense material. After the high energy beta radiation has been attenuated by a low density shielding material (plastic, acrylic, etc.), it may be shielded with lead or other high density materials without generating Bremsstrahlung radiation.

5) Plexiglas, acrylic, or Lucite plastic of 3/8” minimum thickness is recommended for shielding of P-32.

6) Never work directly over an open container of P-32, since the walls of the container (plastic, glass) provide some shielding for the beta radiation.

7) Do not handle containers of P-32 any longer than necessary. Use tongs, work stands, and associated devices to limit direct handling.

8) P-32 is not a significant absorption hazard, but like all unsealed materials may be ingested.

9) The high energy beta associated with P-32 is easily detected with a portable monitoring instrument using a thin window GM detector (efficiency >30%). Work area surveys for contamination may be performed by direct scans and wipe testing as described in Chapter 6, *Radiological Surveys*.

10) In addition to contamination surveys, radiation dose rate surveys should be performed in P-32 laboratories. Radiation dose rates should be measured at 1 foot from use areas, storage locations, and waste containers as described in Chapter 6, *Radiological Surveys*

10.5 Sulfur-35

1) Sulfur-35 (S-35) is primarily an internal hazard. However, direct skin contact with S-35 can result in significant beta exposure to the affected location.

2) S-35 has a radiological half-life of 87.2 days.

3) S-35 has volatile characteristics, especially in the form of cysteine or methionine compounds. Temperature changes promote volatility. Use a fume hood to reduce inhalation risks.

4) Some chemical reactions with S-35 can generate sulfur dioxide or hydrogen sulfide, both of which are gases and therefore an airborne (inhalation) hazard.

5) S-35 is not a significant absorption hazard, but like all unsealed materials may be ingested.

6) Portable survey instruments with thin window GM detectors have a low efficiency for S-35 (approximately 5%), so it is not easily detected by scanning. Direct scanning for contamination must be done slowly (1 to 2 inches per second) in a close proximity (1/2”) to the surface being scanned. Contamination surveys should focus on wipe testing with the wipes counted in a liquid scintillation counter.

10.6 Phosphorus-33

1) Phosphorus-33 (P-33) is primarily an internal hazard. However, direct skin contact with P-33 can result in significant beta exposure to the affected location.

2) P-33 has a radiological half-life of 25.3 days.

3) P-33 is not a significant absorption hazard, but like all unsealed materials may be ingested.

4) Portable survey instruments with thin window GM detectors have an adequate efficiency for S-35 (approximately 15%), so it is easily detected by scanning. Contamination surveys should focus on a combination of scanning wipe testing with the wipes counted in a liquid scintillation counter.

10.7 Tritium

1) Tritium (H-3) is an internal hazard. There is virtually no external radiation hazard because the low energy beta radiation emitted is shielded by the outer layer of skin.

2) H-3 has a radiological half-life of 12.3 years.

3) Because tritium is essentially radioactive water, it may easily enter the body through inhalation, ingestion, or absorption. The most volatile form of tritium is tritiated water.

4) Tritium will penetrate disposable gloves over time. Wear double gloves and change the gloves often to prevent compromising their effectiveness.

5) Portable survey instruments will not detect tritium. Survey for tritium by wipe testing and count the wipes in a liquid scintillation counter.

6) Individuals involved in operations which utilize, at any one time, more than 100 millicuries of tritium in a non-contained form, must have a bioassay performed in accordance with the requirements of Chapter 3, *Radiation Exposure Limits*.

10.8 Carbon-14

1) Carbon-14 (C-14) is primarily an internal hazard. However, direct skin contact with C-14 can result in significant beta exposure to the affected location.

2) C-14 has a radiological half-life of 5730 years.

3) C-14 can become an inhalation hazard. Radioactive carbon dioxide or similar gases may be generated by chemical reactions. Use a fume hood to reduce inhalation risks.

4) C-14 is not a significant absorption hazard, but like all unsealed materials may be ingested.

5) Portable survey instruments with thin window GM detectors have a low efficiency for C-14 (approximately 5%), so it is not easily detected by scanning. Direct scanning for contamination must be done slowly (1 to 2 inches per second) in a close proximity (1/2”) to the surface being scanned. Contamination surveys should focus on wipe testing with the wipes counted in a liquid scintillation counter.

10.9 Other Radioisotopes

The previous information covers the significant hazards associated with some of the commonly used research radioisotopes at UGA. For specific information about the hazards of other radioisotopes, contact Radiation Safety and review any vendor supplied information. You should always be aware of the primary hazards (internal, external, or both) and methods of detecting the radioisotopes that you are using.

10.10 Sealed Sources

1) Sealed radioactive sources are primarily an external radiation hazard. However, sealed sources must be used, handled, and stored in such a manner as to prevent the source from becoming an internal (contamination) hazard.

2) No sealed source may be opened or modified in any way. Sources may not be machined, drilled, cut, or altered.

3) Avoid handling the active surface of sources. Use tweezers, tongs, or other remote handling devices when working with sources that have the potential to produce significant personnel exposure. However, when using remote handling devices, take precautions not to scratch or damage the surface of the source.

4) Do not clean sealed sources with abrasives, chemicals, etc. Avoid other potentially damaging conditions such as temperature extremes, mechanical shock, etc.

5) Sealed sources must be labeled and posted as with any radioactive materials. They are also subject to the same security requirements.

6) Radioactive sources in electronic devices (i.e. gas chromatographs) must not be removed from the detector cells. Do not open or attempt to clean detector cells in these devices.

7) Sealed sources shall be leak tested at a frequency specified by the Radiation Safety Office. A leak testing kit will normally be sent to the Authorized User by the Radiation Safety staff at appropriate intervals.

11.0 USEFUL FORMULAS, CONVERSION FACTORS, AND TABLES

Radioactive Decay

This formula may be used to determine the actual activity of a radioactive source by calculating the correction for radioactive decay. Activity can be in units of curies, dpm, etc.

Elapsed time and half-life must be in the same units (i.e. hours, days, years).

Decay Formula

$A = A_o e^{-0.693\, t / T½}$

Where: A = Activity

A = Original Activity

e = base of natural log

t = elapsed time

T½ = half life

"Rules of Thumb" for Radioactive Decay

- After 7 half-lives the activity of any radioisotope is reduced to <1% of the original value.
- For radioisotopes with half-lives >6 days, the change in activity in a single 24-hour period is <10%.

Inverse Square Law (Point Source)

The inverse square law may be used to calculate the dose rate at a known distance from a radiation source (point source), when another dose rate and distance are known. For example, if a radiation source is generating a known dose rate at 1 foot, you could use this formula to calculate the dose rate at 3 feet.

$$(I_1)\,(D_1)^2 = (I_2)\,(D_2)^2$$

Where:

I_1 = dose rate at 1st distance (initial dose rate)

D_1 = 1st distance (initial)

I_2 = dose rate at 2nd distance (new dose rate)

D_2 = 2nd distance (new distance)

Gamma Exposure Rate Calculation

This formula may be used to calculate the dose rate at one foot from a radioactive source, when the activity of the source in curies and the isotope are known. This formula is effective only for gamma radiation dose rates.

$$I_{\,1ft} = 6CEN$$

Where: I = the gamma dose rate in Rem/hr at one foot

C = the source activity in curies

E = the gamma energy in MeV

N = the photon yield

- Accuracy is approximately 20% for gamma energies from 0.05 to 3 MeV.
- If N is not given, assume 100% photon yield (N=1).
- If more than one photon energy is given, take the sum of each photon energy multiplied by its percentage.

For example, Co-60 emits a 1.173 and a 1.332 MeV gamma, both at a 100% yield. Therefore, the EN value of the equation for Co-60 is (1.173 x 1) + (1.332 x 1) = 2.505

The calculated gamma dose rate at 1 foot from a 100 millicurie Co-60 source would be:

$I_{\,1ft}$ = 6CEN

$I_{\,1ft}$ = 6 x 0.1 Ci x 2.505

$I_{\,1ft}$ = 1.503 Rem/hr = 1,503 mrem/hr

Beta Dose Rate Calculation

The dose rate at 1 cm from a beta emitting point source varies only slightly with differences in energy of the beta radiation. However, note that beta radiation is rapidly attenuated in air.

As a “rule of thumb”, the following equation may be used to estimate the 1 cm (contact) dose rate with a beta emitting point source:

Beta Dose Rate @ 1cm = 300 rad/hr per mCi

The beta dose rate in a solution may be estimated by the following formula:

$$\text{Dose Rate (rad/hr in a solution)} = 2.12 \times E_{avg} \times C$$

Where E_{avg} = the average beta energy in Mev and C = the concentration in µCi/cm^3.

This assumes a density of approximately 1 gram/cm^3.

The dose rate at the surface of the solution will be approximately ½ of the value in the solution.

Beta Particle Energy and Range Estimation

As a “rule of thumb”, the average energy (E_{avg}) of a beta particle is 1/3 of its maximum energy (E_{max}).

For example: P-32 E_{max} = 1.71 MeV, therefore the E_{avg} is approximately 0.6 MeV

The range in air for a beta particle is approximately 12 feet per MeV.

Using the average energy of 0.6 MeV for P-32 gives an average range in air of 7.2 feet. The maximum range in air for a P-32 beta by this calculation is 20 feet.

Based on this thumb rule, a person observing an experiment with P-32 would be unlikely to receive any significant beta radiation exposure if they were more than 7.2 feet from the source

Unit Conversion

Based on a given set of units, you may convert to a desired unit by means of a conversion factor. The conversion factors shown here are ratios of two equivalent physical quantities expressed in different units. When expressed as a fraction, the value of a conversion factor is 1.

Conversion factors in the form of fractions may be built as shown in the following example:

1 millicurie (mCi) of a radioisotope has been diluted in a gallon of solution. What is the activity of the solution in µCi/ml?

Given: 1 mCi/gal, convert to units of µCi/ml

Units:
1 mCi = 1000 µCi
1 liter = 0.26418 gal
1 liter = 1000 ml

The unit conversion formula may be set up as follows:

$$\frac{1\ \cancel{\text{mCi}}}{1\ \cancel{\text{gal}}} \times \frac{1000\ \mu\text{Ci}}{1\ \cancel{\text{mCi}}} \times \frac{0.26418\ \cancel{\text{gal}}}{1\ \cancel{\text{liter}}} \times \frac{1\ \cancel{\text{liter}}}{1000\ \text{ml}} = 0.26418\ \mu\text{Ci/ml}$$

Note that the un-desired units cancel each other out. When only the desired units remain, the conversion has been properly set-up and may be calculated.

Radiological Unit Conversion Factors

Curie units

1 Curie (Ci)	1 E +3 millicurie (mCi)
1 Curie (Ci)	1 E +6 microcurie (µCi)
1 Curie (Ci)	1 E +9 nanocurie (nCi)
1 Curie (Ci)	1 E +12 picocurie (pCi)

Standard activity units

1 Curie (Ci)	3.70 E +10 dps
1 Curie (Ci)	2.22 E +12 dpm
1 millicurie (mCi)	2.22 E +9 dpm
1 microcurie (µCi)	2.22 E +6 dpm
1 nanocurie (nCi)	2.22 E +3 dpm
1 picocurie (pCi)	2.22 dpm

Rem Units

1 rem	1000 millirem (mrem)
1 rem	1 E +6 microrem (µrem)
1 millirem (mrem)	1000 microrem (µrem)

International activity units

1 Megabecquerel (MBq)	1 E +6 dps
1 Becquerel (Bq)	1 dps

Curie to Becquerel conversion

1 Curie (Ci)	37 Gigabecquerels (GBq)
1 millicurie (mCi)	37 Megabecquerels (MBq)
1 microcurie (µCi)	37 kilobecquerels (kBq)
1 nanocurie (nCi)	37 Becquerels (Bq)
1 picocurie (pCi)	37 millibecquerels (mBq)

Becquerel to Curie conversion

1 Terabecquerel (TBq)	27 Curies (Ci)
1 Gigabecquerel (GBq)	27 millicuries (mCi)
1 Megabecquerel (MBq)	27 microcuries (µCi)
1 kilobecquerel (kBq)	27 nanocuries (nCi)
1 Becquerel (Bq)	27 picocuries (pCi)

Rem to Sievert conversion

100 rem	1 Sievert (Sv)
1 rem	10 millisievert (mSiv)
1 millirem (mrem)	10 microsievert (µSv)
1 microrem (µrem)	10 nanosievert (nSv)

Rad to Gray conversion

100 rad	1 Gray (Gy)
1 rad	1 centigray (cGy)
1 rad	10 milligray (mGy)
1 millirad (mrad)	10 microgray (µGy)
1 microrad (µrad)	10 nanogray (nGy)

12.0 ATTACHMENTS

Radiation Worker Certificate (example)

Dosimetry Request Form (example)

Individual Radiation Exposure History Data Sheet (example)