



VIRGINIA POLYTECHNIC INSTITUTE  
AND STATE UNIVERSITY

**Revision Date**  
**June, 2017**

# Radioactive Material Safety



## Program

Environmental Health and Safety  
Radiation Safety  
540-231-5364

# Radioactive Material Safety Program

Environmental Health and Safety  
Health and Safety Building  
575 Beamer Way  
Blacksburg, VA 24061

Phone (540) 231-5364 Fax (540) 231-3944

dcon@vt.edu  
<http://www.ehss.vt.edu>

**REVISION STATUS**

<b>Contact(s)</b>	<b>Implementation Date</b>	<b>Revision Number</b>	<b>Comments</b>
Doug Smiley, Radiation Safety Officer	May, 1986	1.0	Program revised for Document Display System
Doug Smiley, Radiation Safety Officer	October, 1986	2.0	Program revised with minor wording changes, additional information about rinse and decontamination water, change in disposal of long lived liquids and change in violation notices and penalties.
Doug Smiley, Radiation Safety Officer	August, 1987	3.0	Program revised with minor wording changes, new information about bioassay procedures, new information about instrument calibration procedures, additional information about very short half-life wastes, a new section about radioisotope use in animals and decontamination of animal housing.
Doug Smiley, Radiation Safety Officer	December, 1989	4.0	Routine review. Program revised with minor wording changes.
Doug Smiley, Radiation Safety Officer	April, 1991	5.0	Program revised with new procedures for monitoring and control, new information about procedure to receive radioactive material shipments and changed limits and measures of contamination limits in App. B.
Doug Smiley, Radiation Safety Officer	April, 1992	6.0	Routine review. Program revised with minor wording changes.
Doug Smiley, Radiation Safety Officer	February, 1994	7.0	Routine review. Program revised with minor wording changes.
Doug Smiley, Radiation Safety Officer	November, 1994	8.0	Minor changes to reflect changes in Radiation Safety Office.
Doug Smiley, Radiation Safety Officer	December, 2000	9.0	Routine review. Program revised with minor wording changes, reformatted document.
Doug Smiley, Radiation Safety Officer	September, 2008	10.0	Routine review. Program revised with minor wording changes.
Doug Smiley, Radiation Safety Officer	March, 2009	11.0	Program revised to incorporate change from NRC to Virginia regs.

Doug Smiley, Radiation Safety Officer	March, 2011	12.0	Routine review. Program revised with minor wording changes.
Doug Smiley, Radiation Safety Officer	March, 2012	13.0	Routine review. Program revised with minor wording changes to remove 180 day limit for temporary job sites..
Doug Smiley, Radiation Safety Officer	September , 2013	14.0	Routine review. Program revised to modify the Radiation Safety Committee review process of licenses and protocols.
Doug Smiley, Radiation Safety Officer	March-June, 2017	15.0	Routine review. Minor wording changes made throughout document. Program revised to require documented hands-on training, change tritium, <sup>125</sup> I and <sup>131</sup> I bioassay requirements, replace the RSO, remove defect reporting, and require documented surveys at a minimum of monthly frequency.

TABLE OF CONTENTS REVISION STATUS .....	3
TABLE OF CONTENTS .....	5
INTRODUCTION .....	7
RADIATION SAFETY AUTHORITY AND RESPONSIBILITY .....	7
Radiation Safety Committee .....	7
Environmental Health and Safety Department .....	9
Radiation Safety Officer .....	9
Laboratory Authority .....	10
Principal User .....	11
User .....	11
AUTHORIZATION FOR USE OF RADIOACTIVE MATERIAL .....	11
Individual Certification .....	11
Laboratory Certification .....	11
Changes to Authorization .....	12
Inactivation of Authorization .....	12
Reactivation of Authorization .....	12
RADIATION SAFETY TRAINING .....	12
Initial Training .....	12
Hands-on Training .....	13
Refresher Training .....	13
Documentation of Training and Experience .....	13
PERSONNEL MONITORING .....	14
External Exposure .....	14
Internal Exposure .....	14
Exposure Reporting .....	15
RADIATION EXPOSURE LIMITS .....	16
THE ALARA PROGRAM .....	16
PREGNANT RADIATION WORKERS .....	17
DISCIPLINARY PROCEDURES .....	18
Violations and Penalties .....	18
RECEIPT AND TRANSFER OF RADIOACTIVE MATERIAL .....	19
Order Placement .....	19
Order Receipt .....	20
Order Receipt after Regular Hours .....	21
Receipt of Free Radioactive Material .....	21
Transfer of Radioactive Material .....	21
RADIOACTIVE MATERIAL INVENTORY CONTROL .....	21
USE OF RADIOACTIVE MATERIAL AT TEMPORARY LOCATIONS OFF-CAMPUS .....	22
RADIOACTIVE MATERIAL USE IN STUDENT INSTRUCTION .....	23
RADIOACTIVE MATERIAL USE IN ANIMALS .....	23
Animal Housing .....	23
Animal Waste .....	23
Exemptions .....	23
RADIOACTIVE WASTE DISPOSAL PROCEDURE .....	24
Segregation and Storage of Waste .....	24
Dry Solid .....	24
Liquids .....	24
Bulk .....	24
Stock vials .....	24
Liquid scintillation .....	24
Biowaste .....	25
Sanitary Release of Waste .....	25
Waste Removal from Laboratories .....	25
Waste Packaging By Radiation Safety Personnel .....	25
Short-, and Intermediate-Lived Waste (120 days or less) .....	25
Long-Lived Waste (more than 120 days) .....	26

Final Disposition Of Waste.....	27
Short-, and Intermediate-Lived Waste.....	27
Long-Lived Waste .....	28
RECORDS.....	28
EMERGENCY PROCEDURES.....	28
Emergency Actions.....	28
Minor Spills .....	29
Major Spills .....	29
Posting Emergency Procedures .....	29
Emergency Notification Steps .....	30
SECURITY OF RADIOACTIVE MATERIAL.....	30
LABORATORY DESIGN AND SET UP.....	31
Work Areas.....	31
Fume Hoods.....	31
Storage Areas.....	31
Ventilation .....	32
POSTING AND LABELING .....	32
Posting requirements .....	32
Labeling requirements .....	33
LABORATORY INSPECTIONS.....	33
Radiation Safety Office Audits.....	33
Laboratory Self-Audit.....	33
Inactivation of Authorized Equipment or Areas .....	34
SURVEY INSTRUMENTS .....	34
APPENDICES .....	36
APPENDIX 1: Organizational Chart.....	36
APPENDIX 2: Emergency Procedures and Contact Persons .....	37
APPENDIX 3: Emergency Contacts .....	38
APPENDIX 4: Limiting Values .....	39
APPENDIX 5: General Laboratory Radiological Safety Rules and Procedures .....	40
APPENDIX 6: Removable and Fixed Contamination Limits.....	42

## **INTRODUCTION**

### **Purpose**

The Radioactive Material Safety Program details the requirements for and expectations of all university use of radioisotopes, source materials and associated equipment. The program is intended to provide the information needed to work safely with all radioactive material and ensure their security and control for use on campus and off-site locations.

### **Scope**

The program is based on requirements given by the U.S. Nuclear Regulatory Commission, Virginia's Department of Health, Office of Radiological Health and Virginia Tech and covers authorizations, radioisotope stock vial and equipment procurement, security and control, personnel training, worker protection and waste management.

### **Application**

All individuals who use radioactive material are covered by this program. This includes:

- Faculty, staff and students in research laboratories
- Veterinary faculty, staff and students involved in diagnostic and therapeutic nuclear medicine
- Facilities and research personnel using portable or fixed nuclear gauges for moisture, density or elemental analyses.

Any questions for clarification of use should be directed to the University Radiation Safety Office.

## **RADIATION SAFETY AUTHORITY AND RESPONSIBILITY**

The Radiation Safety Committee is the highest decision making body for all radiation safety matters at Virginia Tech. This committee reports to the Vice President for Research and Innovation. The Department of Environmental Health and Safety (EHS) administers the university's radiation safety policies on a daily basis, through its Radiation Safety Group. EHS reports to the Vice President for Administration (see Appendix 1 for the organizational chart).

### ***Radiation Safety Committee***

The university has established the Virginia Tech Radiation Safety Committee (RSC) as a University Operational Committee with the authority to regulate the safe use of ionizing radiation by university personnel. The RSC develops rules for this purpose and oversees their implementation.

Members of the RSC are appointed by the Vice President for Research and Innovation. The Radiation Safety Officer is an *ex officio* member. A representative of the Vice President for Research and Innovation's administrative unit is an *ex officio* member representing university administration. At least two persons trained and experienced in the safe use of radioactive

materials, one person trained and experienced in the safe use of x-ray producing equipment, and other members, as necessary, are appointed on the basis of their experience with radiation. An individual with administrative experience and responsibilities serves as Chair of the Committee. Members of the Committee shall serve a three year term and may be re-appointed for additional terms. A member who misses three consecutive meetings without approval of the Chair for adequate cause will be removed from the Committee.

A meeting of the RSC will be held at least quarterly. The Chair shall call additional meetings as necessary. Minutes of the meetings shall be recorded and distributed to selected persons and maintained for the duration of the license. A quorum shall consist of at least one-half of the members and must include the Chair, the Radiation Safety Officer, and the Administration representative or their designees. Decisions of the RSC shall be based upon approval of a majority of the members present. In the event of a tie, the Chair may vote.

The RSC may delegate its authority to the Chair (or whomever the Chair designates in writing as an alternate), and to the Radiation Safety Officer. The delegates would have the authority to act in the RSC's behalf on such occasions that arise between normal meeting dates that do not warrant a special meeting of the full Committee. An example would be the approval of an authorization amendment, such as the addition or deletion of personnel in an individual laboratory.

The RSC shall:

- review and approve all applications for use of radiation devices and radioactive material by university personnel
- review and approve radiological hazard analyses of new protocols used by investigators. Each new protocol or experiment must include:
  - purpose
  - description
  - analysis of the possible radiation levels produced by the experiment
  - hazards associated with the performance of the experiment
- approve each use of unsealed radioactive material at temporary job sites and monitor the user's operations with these materials and equipment
- ensure any modifications or improvements it considers necessary in the interest of radiation safety or compliance with federal, state, or internal regulations are implemented
- review the radiation protection program content and implementation on an annual basis
- administer disciplinary actions for violations by an *ad hoc* disciplinary subcommittee composed of:
  - RSC Chair (unless an alternate is designated in writing to avoid a potential conflict of interest)
  - Radiation Safety Officer
  - Individuals with experience relevant to the incident (can be from outside the RSC)

Lab licenses, research protocols, and amendments to licenses or protocols are submitted by the Principal Investigator (PI) to the RSO for review.

- The RSO or designee (e.g. a member of the RSC) will perform an initial review of the lab license, research protocol, or amendment, soliciting from the PI any corrections or



clarifications deemed necessary to allow for an adequate review of the procedures and safety precautions.

- The RSO will forward electronic copies of the pre-reviewed application materials to all Committee members for an initial Member Review Preference (MRP) assessment of the application. Members will have 5 working days to respond to the RSC, indicating:
  - that one or more questions/concerns need to be addressed;
  - that the protocol should be held for review and discussion at a convened RSC meeting; or,
  - that the submission may be reviewed and approved by a Designated Member Review (DMR) process.

The absence of a response from an RSC member within the 5 working days time limit will be construed as allowing for DMR review.

- The RSC will delegate its authority for final review and approval of the application to the DMR reviewer. The DMR reviewer may be the Chair, the RSO, or any other member of the RSC so designated by the Chair. The DMR reviewer has the authority to provide final approval on behalf of the RSC. However, the DMR reviewer cannot unilaterally disapprove an application – if the DMR reviewer indicates that she/he cannot approve an application, then that application must be reviewed and acted upon at a convened RSC meeting, with final action determined by a majority vote of the members present at the meeting.

For non-substantive changes, e.g., addition or deletion of personnel in an individual laboratory, those changes can be administratively approved by the Chair or the RSO, and do not require MRP, DMR, or convened RSC meeting action.

### ***Environmental Health and Safety Department***

The Department of Environmental Health and Safety is charged with the responsibility for the coordination of all safety and environmental safety programs at the university not specifically assigned elsewhere. The Radiation Safety Office is a part of this department.

### ***Radiation Safety Officer***

The Radiation Safety Officer (RSO), a staff member of EHS, who by reason of education, training, and experience, is qualified to advise others in the safe use of ionizing radiation and to supervise the health physics program of the university.

The Radiation Safety Officer shall:

- be responsible for personnel monitoring, training, maintenance of exposure records, radioactive material inventories, survey methods, waste disposal and inspections to assure compliance with radiological safety practices
- approve in writing all activities and procedures that involve actual or potential exposure of personnel to radiation or the release of radioactive materials to the environment, and ensure such activities are brought before the Committee for review and approval
- conduct radiological hazard analyses on all new procedures used by laboratories
- be available to consult with all users of ionizing radiation and give advice in radiological safety practices

- suspend any operation causing, or believed capable of causing, an excessive radiation hazard as rapidly as possible
- ensure radiation safety violations are treated according to the Disciplinary Procedures Section of this manual
- perform routine and special radiation surveys as considered necessary in the interest of radiation safety
- provide the RSC a quarterly resume of incidents, inspections, material received, inventory of radioactive material, summary of exposures and a list of authorized users of radioisotopes
- provide the RSC a quarterly report on X-ray laboratories to include a summary of exposures, a current list of authorized users, and any abnormal occurrences
- complete duties in a timely manner

### ***Laboratory Authority***

The Laboratory Authority is the individual designated to be in charge of a given laboratory area or facility. This person is usually a permanent faculty member. A research associate (faculty status) or a sufficiently experienced staff member can be designated if the department head specifically assigns them responsibility for the laboratory.

Where a number of Principal Users share the use of the same facility, the Laboratory Authority is responsible for ensuring that all Principal Users fulfill their responsibilities.

The Laboratory Authority shall ensure:

- the safe operation of all work with radioactive material performed under his or her Authorization
- all laboratory non-users are aware of the radioactive material use areas, storage areas, and methods to avoid the associated radiation hazards
- all persons working under their supervision complete the required radiation safety training before use of radioactivity begins
- all Users under his or her supervision comply with the Virginia Tech Radioactive Material Safety Program (VTRMSP) requirements, as contained in this document, when working with radioactive material
- all Users are familiar with the procedures of an experiment before using radioactive material and have been provided with documented hands-on training
- all required surveys and records are maintained
- proper security is maintained for all radioactive material on his or her Authorization
- their availability on site, within a reasonable length of time (such as 1 hour), when radioactive material is being used and to keep all Users under his or her Authorization informed of where he or she may be reached. This responsibility may be delegated to other principal users, but should be in writing.

- all Users under his or her authorization are informed of all changes to procedures and regulations as they are received
- the Radiation Safety Office is notified whenever an individual may require personnel monitoring and whenever the need for personnel monitoring is terminated

### ***Principal User***

The Principal User can be a permanent faculty member, staff member, or research associate (faculty status). More than one faculty or staff member may be Principal Users on a single Authorization.

Principal Users shall:

- comply, and ensure that all Users under their direction comply, with the VTRMSP requirements
- act as the Laboratory Authority for an Authorization, if designated

### ***User***

A User is a person approved to work with radioactive material under the supervision of a Principal User or Laboratory Authority.

A User shall:

- perform all work with radioactive material in accordance with the VTRMSP requirements

## **AUTHORIZATION FOR USE OF RADIOACTIVE MATERIAL**

The Radiation Safety Committee must authorize all use of radioactive material. This section explains the steps to acquire authorization to use radioactive material.

### ***Individual Certification***

In order to be added to an existing authorization, an individual must fulfill training requirements listed in this document. (See Radiation Safety Training)

### ***Laboratory Certification***

In order for a new laboratory to begin work with radioisotopes, a Virginia Tech "Application for Use of Radioactive Material", all protocols and a radiological hazards analysis must be submitted to the Radiation Safety Office for review. The review includes:

- evaluation of training needs
- evaluation of facilities and equipment
- evaluation of operational and emergency procedures
- RSO review
- consultation with the applicant
- RSC review

The applicant will be permitted to begin operations under terms of the Authorization upon receipt of a copy signed by the Radiation Safety Committee Chair and the Radiation Safety Officer.

### ***Changes to Authorization***

The RSO shall be notified of all changes of personnel, facilities, or operational changes affecting the use of radioisotopes. This notification must be in the form of a written memo, email or web form submission.

The RSO will notify the Lab Authority when changes have been approved.

### ***Inactivation of Authorization***

A lab may choose to terminate all activities or become inactive or the lab may be placed on inactive status if there has been no use of radioactive material in the previous 12 months. The following steps must be taken when this occurs:

- An accurate current inventory of all radioactive materials on the Authorization must be sent to the Radiation Safety Office.
- All material must be transferred to another Authorization or to the Radiation Safety Office for storage or disposal.
- Laboratory personnel must conduct a survey of the laboratory to ensure that there is no contamination of the facility above the levels permitted for unrestricted areas.
- Radiation Safety Personnel will conduct a confirmatory survey of the laboratory to verify that there is no contamination of the facility above the levels permitted for unrestricted areas.

### ***Reactivation of Authorization***

In order to reactivate an Authorization:

- Submit an amendment to the RSO requesting the reactivation.
- Review training tapes designated by the RSO, participate in an oral review on current procedures, or complete the current year's refresher training.

## **RADIATION SAFETY TRAINING**

All persons at Virginia Tech must receive training prior to beginning work with radioactive material.

### ***Initial Training***

Initial training includes the following:

- Review the Radiation Safety Training Manual and the Radioactive Material Safety Program on-line at [http://www.ehss.vt.edu/programs/RMS\\_certification.php](http://www.ehss.vt.edu/programs/RMS_certification.php). The training manual covers the following topics:
  - Fundamentals of Radioactivity
  - Nuclear Reactions
  - Interactions of Radiation with Matter
  - Radiation Detection Instrumentation (theoretical)
  - Radiation Detection Instrumentation (practical)
  - Federal, State and Local Regulations
  - Laboratory Design and Operations
  - Biological Effects
- View a series of videos at [http://www.ehss.vt.edu/programs/RMS\\_certification.php](http://www.ehss.vt.edu/programs/RMS_certification.php)

- Attend Radiation Safety Certification Training given by the Radiation Safety Office that includes:
  - a lecture on principal risks and control measures, contamination surveillance techniques, additional training needs, and emergency actions
  - a comprehensive written test (70 percent is passing) on the material presented
- The RSO may require additional training for an individual laboratory.
- Individuals can become nuclear medicine Principal Users by attending a special lecture that includes the information above as well as additional information specific to the diagnostic and therapeutic use of radioactive material by the College of Veterinary Medicine.
- Individuals who must work ancillary to patients involved in nuclear medicine treatment must complete on-line awareness training found at <http://www.ehss.vt.edu/train.php>

### ***Hands-on Training***

Each laboratory must provide documented operational training to all newly authorized individuals in order to familiarize and increase proficiency with specific techniques. At a minimum, training should include:

- observing actual procedures conducted by experienced personnel
- practicing techniques as mock runs without radioactive material
- performing actual procedures while experienced personnel are present to provide immediate assistance if needed
- understanding lab specific information about contamination monitoring and record keeping

### ***Refresher Training***

All authorized individuals that actively use unsealed sources of radioactive material must complete annual refresher training (required if more than 100 mrem is received in a year) conducted by the RSO which can be found at <http://www.ehss.vt.edu/train.php>. The refresher will:

- emphasize continual awareness of radiation safety concerns
- provide regulatory updates
- review problem areas noted during the previous year

### ***Documentation of Training and Experience***

The training and experience levels of all principal users must be documented and meet the following minimum requirements:

- a bachelor's degree, or equivalent training and experience, in the physical sciences, in biological sciences or in engineering
- forty hours of training and experience in the safe handling of radioactive material, characteristics of ionizing radiation, units of radiation dose and quantities, radiation detection instrumentation, and biological hazards of exposure to radiation appropriate to the type and forms of radioactive material to be used

## **PERSONNEL MONITORING**

### ***External Exposure***

The Radiation Safety Officer will determine whether a personnel monitoring device is needed. Normally, users of radioisotopes **other than**  $^3\text{H}$ ,  $^{14}\text{C}$ ,  $^{35}\text{S}$ ,  $^{33}\text{P}$ , and  $^{125}\text{I}$  will require monitoring devices. A person must wear a monitoring device if he or she enters an area where it is likely to receive an external dose of at least 10 percent of the limits in the Radiation Exposure Limits section. If an exposure over the limits is suspected to have occurred, notify the Radiation Safety Office immediately, so the monitoring device may be processed rapidly.

The monitoring devices will be optically stimulated luminescent dosimeters (OSLD), thermoluminescent dosimeters (TLD), and/or pocket dosimeters, unless the Radiation Safety Officer authorizes other devices.

When a TLD or OSLD is used, the badge will be processed:

- on a monthly basis (or more often as determined by the RSO) where significant exposures are possible, or
- on a quarterly basis where exposures are expected to be low.

Pocket dosimeters will be worn when indeterminate levels of radiation are suspected, or as required by the RSO.

Monitoring devices will be worn as follows:

- Monitoring devices must be worn at body locations where the highest potential doses are expected.
- Body badges should normally be worn in the upper chest area.
- Finger badges should be worn on the hand closest to the source of radiation and usually facing inward.
- When not in use devices must be stored in areas where they will not be exposed to radiation.
- Badges must not be worn during non-occupational exposure, e.g. medical x-rays.
- **Personnel monitoring badges may not be used for anything other than determining personnel doses unless prior approval is given by the RSO. This would include using them for procedure or work area level quantifications.**
- **Caution – if you travel by air, put personnel monitoring badges in carry-on luggage instead of checked luggage. Checked luggage receives significant x-ray exposure during screening when compared to the very low x-ray exposure received by carry-on luggage being screened.**
- **Caution – personal nuclear medicine procedures can cause non-occupational exposures to be recorded on monitoring devices so before undergoing any nuclear medicine procedures, contact the Radiation Safety Office to discuss special steps needed.**

### ***Internal Exposure***

Internal dose assessments are made at the discretion of the Radiation Safety Officer based upon potential intake or if an individual requests it. These may consist of the following:

- urine specimens in the event of an incident where potential uptake is suspected

- bioassays if there is an accident or an unusual experiment involving a known or suspected hazardous condition when it is likely that an uptake of 10% of the Annual Limit of Intake (ALI) has occurred
- bioassays when individuals work with tritiated ( $^3\text{H}$ ) compounds in quantities greater than 10 mCi/month outside of a fume hood or 100 mCi/month inside of a fume hood
- thyroid analysis when individuals use unbound  $^{125}\text{I}$  or  $^{131}\text{I}$  in quantities of 0.1 mCi in an open room or 1 mCi in a fume hood or bound  $^{125}\text{I}$  or  $^{131}\text{I}$  in quantities of 1 mCi in an open room or 10 mCi in a fume hood at any one time or over a three-month period
  - Thyroid analysis should be performed within 6-72 hours of the potential exposure, but 24 – 48 hours is the optimum time.

Bioassays will consist of:

- Urinalyses for gross beta activity for most radioisotopes performed by the RSO or an outside vendor.
- Thyroid analysis for  $^{125}\text{I}$  uptake performed by Radiation Safety personnel using a thin NaI detector system as necessary.
- Thyroid analysis for  $^{131}\text{I}$  uptake performed by Radiation Safety personnel using a thick NaI detector system as necessary.
- Other bioassay methods may be chosen by the RSO.

Corrective actions by the RSO for positive results are listed below:

- When bioassay results exceed 10 percent of the appropriate ALI from Virginia regulation 12VAC5-481-3690:
  - Investigate laboratory operations involved, including air and area surveys as appropriate, to determine the cause and evaluate the potential for further exposures
  - If the investigation indicates problems in the work area that could result in further exposures to personnel, additional work in the area will be avoided until the cause is discovered and corrected
  - Corrective actions that will eliminate or lower the potential for further exposures will be implemented in a timely manner
  - A repeat bioassay should be done within one week of the previous sample to confirm the uptake and determine the effective half-life for estimating dose commitment

**NOTE: The above actions are required when a tritium bioassay shows more than 5 uCi/L; or when a  $^{125}\text{I}$ ,  $^{131}\text{I}$  bioassay shows more than 1 uCi.**

- When bioassay results exceed 25 percent of the appropriate ALI, the following steps, in addition to those above, will be performed:
  - Obtain appropriate medical assistance to provide therapeutic measures as necessary to accelerate the biological elimination of the radioactive material from the body
  - Take weekly bioassays until the results do not exceed 10 percent of the appropriate ALI

**NOTE: The above actions are required when a tritium bioassay shows more than 50 uCi/L; or when a  $^{125}\text{I}$ ,  $^{131}\text{I}$  bioassay shows more than 5 uCi.**

### ***Exposure Reporting***

The Radiation Safety Office maintains all personnel monitoring records. Individuals should provide prior records of radiation exposure.

Radiation exposure results will be provided as necessary, usually on an annual basis. Each user will receive reports on an annual basis if that person is likely to receive in excess of 10% of the annual exposure limits.

**RADIATION EXPOSURE LIMITS**

No person will be permitted to receive a radiation dose in one calendar year in excess of those listed in this section. The limits are from 12VAC5-481-640.

**Occupational Limits**

Type of Individual	Region of the Body	Limit (per year)
Adults (18 years or more)	Total effective dose equivalent (TEDE) Whole body; head, trunk, gonads, arms above the elbow or legs above the knee; external and internal dose	5,000 mRem
	Lens dose equivalent (LDE) Lens of the eye	15,000 mRem
	Shallow dose equivalent (SDE) Skin of body; extremities - hand, elbow, arm below the elbow, foot, knee, leg below the knee	50,000 mRem
Declared pregnant worker	TEDE	500 mRem per pregnancy
Minors (under 18 years of age)	TEDE	500 mRem
	LDE	1,500 mRem
	SDE	5,000 mRem
General Public	TEDE	100 mRem

No individual in a restricted area can be exposed to airborne radioactive material in concentrations above those specified in 12VAC5-481-3690. If an internal uptake in excess of 10 percent of the ALI is determined, the TEDE will include the committed effective dose equivalent (CEDE) added to the deep dose equivalent (DDE).

**THE ALARA PROGRAM**

The university is committed to keeping radiation exposures *As Low As Reasonably Achievable* (ALARA). Under the ALARA program certain exposure levels require investigation.

**ALARA Investigation Levels**

Type of Individual	Region of Body	Level I (per year)	Level II (per year)
Adults	TEDE	500 mRem	1,250 mRem
	LDE	1,500 mRem	3,750 mRem
	SDE	5,000 mRem	12,500 mRem
Declared pregnant worker	TEDE	50 mRem per pregnancy	125 mRem per pregnancy
Minors	TEDE	50 mRem	125 mRem
	LDE	150 mRem	375 mRem
	SDE	500 mRem	1,250 mRem



General Public	TEDE	10 mRem	25 mRem
----------------	------	---------	---------

The RSO will review and record results of personnel monitoring at least once for each calendar quarter.

The following actions will be taken:

- For personnel dose less than Investigational Level I:
  - no further action will be taken unless deemed appropriate by the RSO
- For personnel dose equal to or greater than Investigational Level I but less than Investigational Level II:
  - RSO will review the appropriate dose results
  - Report the results of the reviews at the first RSC meeting following the quarter when the level was exceeded
  - RSC dose review comparing the doses of others performing similar tasks as an index of ALARA program quality
  - The review will be recorded in the RSC minutes
  - No further action will be taken unless deemed appropriate by the RSC
- For personnel dose equal to or greater than Investigational Level II:
  - RSO will investigate into the causes and take any necessary action
  - RSO will provide an investigation report, actions taken, and a copy of the individual's exposure record to the RSC at its first meeting following completion of the investigation
  - Details of these reports will be recorded in the RSC minutes

Investigational Levels may be established to levels above those listed in this section and involves the following:

- establish a new level for an individual or group that it is consistent with good ALARA practices
- document the justification
- RSC review and approval of all revisions

### **PREGNANT RADIATION WORKERS**

A User has the option to formally declare a pregnancy to their supervisor in order to take advantage of reduced occupational exposure limits for the entire term of the pregnancy. This declaration is voluntary and can be kept confidential. The RSO is available to answer any questions that may arise whether or not a formal declaration of pregnancy is made. To become a declared pregnant worker the supervisor needs the following information:

- estimated month of conception
- expected date of birth

The RSO ensures that:

- all declared pregnant authorized users reduce their doses as necessary in conformance with the guidelines established in Regulatory Guide 8.13, "Possible Health Risks To Children Of Women Who Are Exposed To Radiation During Pregnancy"
- if a declared pregnant worker has received more than 450 mRem (TEDE) when the pregnancy is declared, then she cannot receive over 50 mRem (TEDE) during the remainder of the pregnancy

## **DISCIPLINARY PROCEDURES**

Failure to follow the radiation safety guidelines found in this document may result in disciplinary procedures initiated against a Laboratory Authority or responsible individual. Penalties for violations will be assessed at the discretion of the RSO and the Radiation Safety Committee.

### ***Violations and Penalties***

- Class I - Administrative or procedural deficiency of a relatively minor nature, e.g., failure to maintain survey records properly. If three citations are issued within a 1-year period, operations under an Authorization will automatically be suspended, pending a review by the Radiation Safety Disciplinary Subcommittee.
  - A Notice of Concern (NOC), issued by the Radiation Safety Officer, will explain the nature of the violation and the potential for incurring further disciplinary actions. At the discretion of the Radiation Safety Officer, the NOC can be issued as a warning or a first citation can be issued. A copy of the NOC will be kept on file.
  - First Citation-The Chair of the Radiation Safety Committee will issue a letter of reprimand with a copy to the department head.
  - Second Citation-An immediate cessation of operations under an Authorization will be required, normally in effect for two weeks. This action may be changed, pending a review by the Radiation Safety Disciplinary Subcommittee. A letter of reprimand will be issued by the Chair of the Committee and will be copied to the Department Head, and Dean of the college involved.
  - Third Citation-An immediate cessation of operations under an Authorization will be required, pending review of the incident by the Radiation Safety Disciplinary Subcommittee. A suspension letter will be sent by the Chair of the Committee and will be copied to the Department Head, Dean of the college involved, and the Vice President for Research and Innovation. After a period of no more than one year, the Committee will review reinstatement of the Authorization.
- Class II - Major violations that could result in excessive radiation exposures to personnel, or willful and repeated negligence (e.g., loss of radioactive material due to negligence; improper use of radioactive materials in such a way as to lead to potential injury or liability). An immediate cessation of operations under an Authorization will be required, pending review of the incident by the Radiation Safety Disciplinary Subcommittee. A suspension letter will be sent by the Chair of the Committee and will be copied to the Department Head, Dean of the college involved, and the Vice President for Research and Innovation. After a period of no more than one year, the Committee will review reinstatement of the Authorization.

Citations will normally be issued to the Laboratory Authority. However, in situations beyond the Laboratory Authority's control, such as willful negligence by an individual, citations can be issued to the specific person responsible. The Disciplinary Subcommittee will make this determination. **Any cited individual has the right to appear before the subcommittee to assist in the determination of the class of citation and to appeal any action of the Disciplinary Subcommittee to the Radiation Safety Committee.**

A preliminary determination of the class of violation will be made at an interim meeting of the Radiation Safety Officer and the Chair of the Radiation Safety Committee. A review of Class I

first violations will take place at the next regularly scheduled meeting of the Radiation Safety Committee. A meeting of a Disciplinary Subcommittee will be convened by the Chair as soon as practical for Class I second and third violations and for Class II violations.

The Disciplinary Subcommittee will determine the appropriate action to take for all Class I violations for second and third offenses and for Class II violations. The Disciplinary Subcommittee is empowered to impose the disciplinary actions decided upon. However, the Radiation Safety Committee will review the decisions of the Subcommittee at the next regularly scheduled meeting or the Chair will call a meeting as soon as practical upon an appeal by the cited individual. The Radiation Safety Committee may approve or modify the actions of the Disciplinary Subcommittee as the final authority on radiation safety matters at the University.

The results of any disciplinary action taken by the Radiation Safety Disciplinary Subcommittee, after their consideration of the incident and of any appeals made to the Radiation Safety Committee, will be sent to the same individuals to whom the original materials were sent.

## **RECEIPT AND TRANSFER OF RADIOACTIVE MATERIAL**

### ***Order Placement***

Radioisotopes must be purchased through the HokieMart system. Please note the following when completing a request:

- Use the shipping code "D423" to specify the correct (EHS) ship to address
- Use "Donald Conner / Dr. {insert Laboratory Authority's name here}" for contact name
- Phone number must be 540-231-5364
- Email address is, "dcon@vt.edu"
- Specify shipping via "Best Carrier-Priority Overnight" (this allows orders to be delivered to labs in the afternoon after receipt in the morning)
- Specify account number of "13415"
- Add an internal note with the radioisotope and activity if not already noted in the catalog line item
- Add an external note stating delivery time, e.g. "Delivery xx/xx/xx AM; Please provide confirmation to dcon@vt.edu"

HokieMart orders are reviewed and approved several times each day, but be sure to allow sufficient time for the requesting department to process internally so that the request is received by Radiation Safety **no later than noon the day before you need the material.** <sup>32</sup>P and <sup>33</sup>P nucleotides can be shipped the same day as ordered but most other compounds cannot be shipped on the same day as ordered. Some compounds cannot be shipped over a weekend.

**NOTE: Often HokieMart does not show our discounted pricing, but the vendors actually use correct pricing on the invoice.**

**NOTE: There are exceptions for the College of Veterinary Medicine. The Blacksburg VTH places orders with emails to the RSO. The Leesburg EMC places orders directly with a Northern Virginia radiopharmacy.**

**All radioactive material must be shipped to:**

Virginia Tech  
Radiation Safety Office, (MC0423)  
Materials Management Facility  
625 Beamer Way  
Blacksburg, Virginia 24061  
Attn: User's Name

***Order Receipt***

The Radiation Safety Office should receive all radioactive material. During normal working hours, the carrier should place the package in the designated lock-box.

The procedure **followed by the Radiation Safety Office** for receipt of packages, usually within 3 hours of arrival, is:

- Visually inspect the package for any sign of damage.
- Perform instrument surveys to ensure that exposure limits are not exceeded:
  - If the package is labeled as White I, Yellow II or Yellow III, or evidence of damage is present
    - White I limit is 0.5 mr/hr on contact
    - Yellow II limit is 50 mr/hr on contact, 1 mr/hr at 1 meter
    - Yellow III limit is 200 mr/hr on contact, 10 mr/hr at 1 meter
- Contact VDH at 800-468-0138 or 800-468-8892 after hours (Virginia Department of Health, Office of Radiological Health) and the final delivery carrier if radiation levels exceed:
  - 200 mrem/hr on the package surface
  - 10 mrem/hr at 1 meter from the package surface
- Wipe test the external surface of each package to ensure that removable contamination limits are not exceeded if:
  - the package is labeled as White I, Yellow II or Yellow III, or
  - evidence of damage is present
  - Contact VDH at 800-468-0138 or 800-468-8892 after hours and the final delivery carrier if removable contamination levels on the package surface are in excess of 22,000 dpm/100 cm<sup>2</sup>
- Verify that the packing slip agrees with the purchase request.
- Place the appropriate information in the Package Receipt Log.
- Deliver the package to the appropriate laboratory.

The procedure **followed by Laboratory personnel** for receipt of packages is:

- Wear gloves to prevent hand contamination.
- Remove the packing slip.

- Open the outer package following the vendor's instructions, if provided.
- Open the inner package and verify that the contents agree with the packing slip.
- Check the integrity of the final source container. Look for broken seals or vials, loss of liquid, condensation, or discoloration of the packing material. Survey your gloves after handling the stock vial.
- If anything is other than expected, stop and immediately notify the Radiation Safety Office.
- Monitor the packing material and empty package for contamination with an appropriate survey meter or wipe test before discarding.
  - If greater than 220 dpm, treat this material as radioactive waste and notify the RSO.
  - If not contaminated, remove or obliterate the radiation labels before discarding in normal trash.
- Record the receipt in the appropriate log.
- Open packages within 3 hours of receipt.

### ***Order Receipt after Regular Hours***

An authorized user must make special arrangements with the RSO in advance for packages to be received after regular hours. **RSO personnel will arrange with the carrier to receive such packages at specific times.** Once delivered, the package receipt procedures listed above must be followed.

### ***Receipt of Free Radioactive Material***

- Prior approval from the RSO is necessary for any radioactive material to be received at Virginia Tech.
- Order receipt procedures listed above must be followed.

### ***Transfer of Radioactive Material***

For lab to lab transfers, submit an internal transfer request for RSO approval by e-mail or web page (web preferred).

For Off-Campus transfers, contact the Radiation Safety Office. The RSO will:

- properly label and manifest each package
- pick up the package from the laboratory
- ensure that the recipients are authorized by a federal or state agency to possess the material being sent
- ship the package to the authorized recipient

### **RADIOACTIVE MATERIAL INVENTORY CONTROL**

Strict control of radioactive material prevents any possession limits from being exceeded. A computer program is used to maintain individual laboratory and university running totals of radioactive material. The program will not allow orders to be placed if they will exceed laboratory or university possession limits. The university inventory control consists of the following:

- RSO approval is required for any receipt of radioactive material
- Upon material receipt the laboratory verifies the contents
- Waste removal from laboratories is documented

- Transfers from one laboratory to another are documented
- Transfers from a laboratory to external locations are documented
- Waste disposal from the university is documented
- Sealed sources of radioactive material are inventoried on a semi-annual basis
- Unsealed sources of radioactive material are inventoried on an annual basis

**USE OF RADIOACTIVE MATERIAL AT TEMPORARY LOCATIONS OFF-CAMPUS**

Authorized users may conduct research activities at temporary job sites remote from the main campus. The temporary job sites may be located on university property or non-university property. The radioactive material may be in the form of sealed or unsealed sources of radioactivity.

**Requirements for Use at Temporary Job Sites**

<b>Owner of Job Site</b>	<b>Sealed Sources</b>	<b>Unsealed Sources</b>
<b>University</b>	<ul style="list-style-type: none"> <li>• transport in a secure fashion in accordance with DOT regulations</li> <li>• lock any unattended material</li> </ul>	<ul style="list-style-type: none"> <li>• transport in a secure fashion in accordance with DOT regulations</li> <li>• outside of container cannot exceed 220 dpm/100 cm<sup>2</sup></li> <li>• lock any unattended material</li> <li>• radiation and contamination surveys required daily, weekly and/or monthly</li> <li>• close-out survey completed before release of site for unrestricted use. A copy of the close-out survey will be provided to VDH.</li> </ul>
<b>Non-university</b>	<ul style="list-style-type: none"> <li>• transport in a secure fashion in accordance with DOT regulations</li> <li>• lock any unattended material</li> <li>• RSO must receive a written agreement signed by property owner. Agreement must establish radiation safety responsibility, describe use, and describe site clearance.</li> </ul>	<ul style="list-style-type: none"> <li>• transport in a secure fashion in accordance with DOT regulations</li> <li>• outside of container cannot exceed 220 dpm/100 cm<sup>2</sup></li> <li>• lock any unattended material</li> <li>• radiation and contamination surveys required daily, weekly and/or monthly</li> <li>• close-out survey completed before release of site for unrestricted use. A copy of the close-out survey will be provided to VDH.</li> <li>• RSO must receive a written agreement signed by property owner. Agreement must establish radiation safety responsibility, describe use, and describe site clearance.</li> </ul>

## **RADIOACTIVE MATERIAL USE IN STUDENT INSTRUCTION**

Provisions must be made to enable the safe use of radioisotopes by students under well-supervised conditions. The following steps must be taken for any use of radioisotopes by students in a classroom setting:

- Submit a basic protocol to the RSO prior to the use of radioactive material by students
- The RSO will determine if radiation safety training will be required. When students will use small quantities of radioactive material, the training can be minimal. However, if quantities in excess of the values in Appendix 4 will be used, a fully documented radiation safety training session must be given. The RSO will usually provide this session.
- Professors and teaching assistants (GTAs) must be approved radioisotope users and added to the appropriate authorizations before the start of the class
- The location of the laboratories must be approved and added to the appropriate authorizations
- A list of all students participating in the laboratory must be submitted to the Radiation Safety Office
- All work with radioisotopes by students must be done under supervision of teaching assistants as a minimum

## **RADIOACTIVE MATERIAL USE IN ANIMALS**

### ***Animal Housing***

- Only approved Users can provide animal care.
- Animals should be housed in areas normally unoccupied by personnel.
- Rooms or areas in which animals are housed must be posted as a Radioactive Material Area.
- After animals and bedding materials have been removed from the housing (cages, runs or stalls), a contamination survey must be performed using the following steps:
  - If less than 1 microcurie is present, the housing can be washed with copious amounts of water
  - If more than 1 microcurie is present, the housing should also be washed with copious amounts of water, but the activity disposed must be recorded
  - After the housing is dry, a contamination survey must be performed. Continue with washing and survey cycle until area is clean.
  - Once housing is clean, normal access can be restored

### ***Animal Waste***

- Any used bedding material must be treated as radioactive waste and prepared as specified in the radioactive waste disposal section.
- Any animal carcasses must be treated as radioactive waste and prepared as specified in the radioactive waste disposal section.

### ***Exemptions***

The College of Veterinary Medicine nuclear medicine program is exempted from housing survey, storage of carcasses, and equine bedding waste disposal requirements noted above.. Separate procedures exist for nuclear medicine operations.

## **RADIOACTIVE WASTE DISPOSAL PROCEDURE**

All receptacles and packages containing waste must be labeled (or similar words) "Caution -- Radioactive Material" or "Caution -- Radioactive Waste".

Waste is segregated based on half-life and physical characteristics to facilitate collection and disposal as follows:

By Half-life:

- short half-life (less than 30 days; e.g.  $^{131}\text{I}$ ,  $^{32}\text{P}$ ,  $^{33}\text{P}$  and  $^{51}\text{Cr}$ )
- intermediate half-life (30 - 120 days; e.g.,  $^{125}\text{I}$  and  $^{35}\text{S}$ )
- long half-life (120 days or longer; e.g.  $^{14}\text{C}$ ,  $^3\text{H}$ ,  $^{36}\text{Cl}$  and  $^{45}\text{Ca}$ )

By Physical Characteristics:

- Dry solid waste- primarily composed of paper, plastic or glass. **Liquids are not allowed in this type of waste.**
- Liquid waste- either aqueous or nonaqueous in very small or bulk volumes
- Biowaste- composed of animal carcasses, blood, animal excretions or bedding tainted with excretions

### ***Segregation and Storage of Waste***

Dry Solid

- Collect waste in plastic-lined 5-gallon, 20-gallon, 30-gallon, or 55-gallon containers provided by the Radiation Safety Office.
- Collect sharps waste (e.g. Pasteur pipettes, other glass pipettes, broken glass, razor blades, and capped syringes) in well-marked, puncture-resistant containers to prevent sticking hazards to personnel who handle the waste. Segregate from other solid waste.
- Prior to removal from the laboratory, activity estimates must be determined for each isotope in the container. The estimates should be as exact as possible.

Liquids

Bulk

- Collect bulk liquids in 1-gallon or 2.5-gallon plastic or safety coated glass containers provided by the RSO.
- All original solutions and first rinses must be collected as bulk liquid waste.
- Segregate aqueous liquid from nonaqueous liquid.
- Determine activities for each isotope in the container by analyzing aliquots from each container converting to total container activity in microcuries ( $\mu\text{Ci}$ ).

Stock vials

- Small volume, high activity vials (stock vials) that are either unused or partially used must be segregated from all other liquid waste and collected in plastic-lined 5-gallon containers. (Exception: short and intermediate stock vials can be disposed in solid waste containers)
- Activity estimates must be determined for each isotope in the container.

Liquid scintillation

- Collect vials in plastic-lined 5-gallon, 20-gallon, 30-gallon or 55-gallon containers.
- Segregate according to specific activity (less than or greater than  $0.05 \mu\text{Ci/ml}$ ).



- Segregate  $^3\text{H}$  and  $^{14}\text{C}$  from other isotopes. Segregate other isotopes with a half life over 120 days from all other isotopes.
- Activity estimates must be determined for each isotope in the container.

### Biowaste

- Animal carcasses and bedding containing excretions are collected in plastic bags or plastic containers.
- Waste must be maintained frozen until removed by radiation safety personnel.
- Biowaste with specific activities of  $^3\text{H}$  and  $^{14}\text{C}$  less than  $0.05 \mu\text{Ci/g}$  must be kept separate from any other isotopes.
- Activity determinations must be made. The activity originally administered to the animal normally provides a reasonable estimate of the activity in the carcass.
- Veterinary Medicine nuclear medicine program carcasses are to be segregated in walk-in coolers.

**NOTE: Mixed waste generation must be minimized and segregated from other radioactive waste. Mixed waste has radioactive and chemical constituents (e.g., acid or base).**

### ***Sanitary Release of Waste***

Secondary and subsequent rinses can be released into the sanitary system if all the following are met:

- the liquid is readily soluble (or is readily dispersible biological material) in water
- the total release for the laboratory is not greater than 1 microcurie per day
- the release is flushed with copious amounts of water

### ***Waste Removal from Laboratories***

- Radiation Safety personnel remove waste from laboratories on a weekly basis (usually Wednesdays).
- The laboratory must request pickups as needed by the web page.
- Each waste container must be properly labeled with a "Radioactive Waste" label. This must include the following:
  - the waste preparer and Authorization number
  - the isotope(s)
  - the activity corrected for decay in microcuries
  - chemical constituents and their percentage of the total (not required for solid waste)
  - container contamination check results
  - the waste type
- Only one waste type can be marked on each label.
- The laboratory must retain records of waste removal.

### ***Waste Packaging By Radiation Safety Personnel***

Short-, and Intermediate-Lived Waste (120 days or less)

- **Dry Solid**

- A plastic liner is placed in a 55-gallon drum. After the drum is filled with waste, the bag is twisted shut and secured with tape. A gasketed lid is bolted onto the drum with a closure ring. The drum is then numbered with an indelible marker.
- Short-lived waste is packaged separately from intermediate-lived waste.
- **Liquids**
  - Bulk aqueous liquids are released into the sanitary system approximately once per month. Prior to release into the sanitary system, an aliquot from each container is analyzed to independently confirm the generating laboratories' activity determinations. The sanitary releases do not exceed the release limits specified in 12VAC5-481-3690.
  - Nonaqueous liquids (mixed waste – chemical and radioactive constituents) are segregated and held until 10 half-lives have elapsed. After the decay period, the liquid waste is assayed and added to the chemical waste disposal program once all radioactivity is gone.
  - Small volume, high activity aqueous vials (stock vials) are placed into solid waste drums. Nonaqueous high activity mixed wastes are held until 10 half-lives have elapsed. After the decay period, the liquid waste is assayed and added to the chemical waste disposal program once all radioactivity is gone.
  - Liquid scintillation fluid in vials is packaged according to the specific activity of the fluid and the specific isotopes present. Specific activities less than 0.05  $\mu\text{Ci/ml}$  of  $^3\text{H}$  and  $^{14}\text{C}$  are segregated from all other isotopes. Liquid scintillation vials are packaged by adding six inches of absorbent to a plastic-lined 55-gallon drum. A second liner is put in the drum, and then the drum is filled with vials. Each plastic liner is twisted shut and secured with tape. A gasketed lid is bolted onto the drum with a closure ring. The drum is numbered with an indelible marker. After the decay period, the liquid scintillation waste is added to the chemical waste disposal program once all radioactivity is gone.
- **Biowaste**
  - Carcasses and bedding are not packaged in drums because of biological degradation. They are maintained frozen until 10 half-lives have elapsed. After the decay period, the biowaste is surveyed and sent to the landfill or other appropriate disposal means once all radioactivity is gone.

A general exception to the short-lived waste rules applies to the veterinary nuclear medicine waste containing  $^{99\text{m}}\text{Tc}$ . VTH and EMC personnel collect, package, hold for 10 half-lives, survey and discard once all radioactivity is gone.

#### Long-Lived Waste (more than 120 days)

- **Dry Solid**
  - Dry waste is packed in a plastic-lined 55-gallon drum when destined for supercompaction. Once the drum is full, the plastic liner is twisted shut and secured with tape. A gasketed lid is bolted onto the drum with a closure ring. The drum is numbered with an indelible marker.
  - Dry waste is packed in a plastic-lined fiber container when destined for incineration. Once the container is full, the plastic liner is twisted shut and secured with tape. The container is secured with tape usually. The container is numbered with an indelible marker.
- **Liquids**

- Bulk aqueous liquids are released into the sanitary system approximately once per month. Prior to release into the sanitary system, an aliquot from each container is analyzed to independently confirm the generating laboratory's activity determinations. The sanitary releases do not exceed the release limits specified in 12VAC5-481-3690.
- Any bulk aqueous liquids not released to the sanitary system are solidified in concrete and packed in 30- or 55-gallon drums. A gasketed lid is bolted onto the drum with a closure ring. The drum is numbered with an indelible marker.
- Bulk nonaqueous liquids are collected in 15 or 30-gallon drums for disposal by incineration. The drum is numbered with an indelible marker.
- Small volume, high activity aqueous vials (stock vials) are placed into solid waste drums. Nonaqueous high activity mixed wastes are held until they can be processed for incineration.
- Liquid scintillation fluid in vials is packaged according to the specific activity of the fluid and the specific isotopes present. Specific activities less than 0.05  $\mu\text{Ci/ml}$  of  $^3\text{H}$  and  $^{14}\text{C}$  are segregated from all other isotopes. Liquid scintillation vials are packaged by adding six inches of absorbent to a plastic-lined 55-gallon drum. A second liner is put in the drum, and then the drum is filled with vials. Each plastic liner is twisted shut and secured with tape. A gasketed lid is bolted onto the drum with a closure ring. The drum is numbered with an indelible marker.
- **Biowaste**
  - Specific activity also determines the disposal method for biowaste. Those with less than 0.05  $\mu\text{Ci/g}$  of  $^3\text{H}$  and  $^{14}\text{C}$  are disposed without regard to their radioactivity. All other biowaste must be packaged for disposal.
  - For biowaste that is packaged for disposal by incineration, a plastic lined special plastic or fiber container is filled. The plastic liner is twisted shut and secured with tape. The container is secured with tape usually. The container is numbered with an indelible marker.

### ***Final Disposition Of Waste***

#### **Short-, and Intermediate-Lived Waste**

- Drums are surveyed for radiation using portable GM or ion-chamber survey instruments. Contamination surveys are performed with filter paper swipes that are analyzed in a liquid scintillation counter. Then the drums are transported to the Waste Storage Building and stored for 10 half-lives.
- After this decay period the waste is either processed by a vendor or processed in-house. The waste is surveyed to ensure that the waste has reached background levels. During the survey process, any "Caution -- Radioactive Material" labels are obliterated and lead shields are removed from the waste. The cleared waste is disposed of according to type:
  - dry solids to the landfill or medical incinerator,
  - lead waste to recycling,
  - radioactive material labels are obliterated or burned,
  - liquids to the sanitary system, and
  - biowaste to the landfill or other appropriate disposal means.

- A general exception to the short-lived waste rules applies to the veterinary nuclear medicine waste containing  $^{99m}\text{Tc}$ . VTH and EMC personnel collect, package, hold for 10 half-lives, survey and discard once all radioactivity is gone.

### **Long-Lived Waste**

- Containers are surveyed for radiation and contamination levels as in the previous section. The containers are stored in the Materials Management Facility to await removal by a commercial firm. Approximately once every 6 months, a radioactive waste broker is contacted to arrange for final removal from the university. The containers are labeled in accordance with DOT regulations and manifested. A shipment must have its receipt acknowledged within 20 days. If not acknowledged, the shipment must be traced and reported, in writing, to VDH within 2 weeks of completion of the investigation.

### **RECORDS**

The Radiation Safety Officer maintains the following information:

- Current List of approved Users
- Personnel Exposure (including information required on NRC Form 5 or equivalent)
- Radioactive Material Inventory
  - receipt
  - assignment
  - final disposition
- Radiation Surveillance
  - radiation surveys
  - contamination surveys
  - air sample surveys
- Radioactive Waste Disposal
  - container surveys
  - manifests
  - all other disposal records
- Instrument Calibration Documentation

All laboratories must maintain the following information:

- a record of each radioisotope in their possession including:
  - receipt
  - usage
  - final disposition
- a record of contamination and/or radiation surveillance

### **EMERGENCY PROCEDURES**

Emergencies must be responded to quickly so adverse effects can be minimized. This section describes the types of emergencies, emergency actions and posted information. Radiation emergencies are classified as non-reportable minor spills or reportable major spills.

### ***Emergency Actions***

The following emergency actions must be taken immediately upon discovery of a spill.

## Minor Spills

Areas or equipment that have become contaminated. The affected area must not involve more than 1 millicurie (100 millicuries of  $^{99m}\text{Tc}$ ) of radioactivity and must be a small area.

- NOTIFY COWORKERS: Notify persons in the area and the Laboratory Authority that a spill has occurred.
- PREVENT THE SPREAD: Cover the spill with absorbent paper.
- CLEAN UP: Use disposable gloves; use remote handling tongs if necessary. Carefully fold the used absorbent paper and place into a plastic bag. Also insert into the plastic bag all other contaminated materials such as disposable gloves. Carefully clean the affected area with decontamination solution. Put the plastic bag into a radioactive waste container.
- SURVEY: Using a suitable radiation survey meter (for isotopes other than  $^3\text{H}$ ), check the area around the spill, hands, and clothing for contamination. Survey the area with wipe samples to ensure that levels are below 220 dpm/100 cm<sup>2</sup>.
- CALL RSO FOR HELP: Contact the Radiation Safety Office (RSO) if any assistance is needed. During normal working hours, call 540-231-5364. If no one answers, immediately call the Virginia Tech Police at 911. After normal working hours, call the Virginia Tech Police at 911 and tell the dispatcher there is a radiation emergency.

## Major Spills

Large affected areas, and/or not confined to one room, and/or difficult to clean up, and/or has a tracking potential, and/or has airborne radioactivity potentials (e.g. fine powders, volatiles or gases). The area may involve more than 1 millicurie (100 millicuries of  $^{99m}\text{Tc}$ ) of radioactivity.

- CLEAR THE AREA: Notify all persons not involved in the spill to vacate the room. Notify the Laboratory Authority that a spill has occurred.
- PREVENT THE SPREAD: Cover the spill with absorbent paper or pads, but do not attempt to clean it up. Confine the movement of all potentially contaminated personnel to prevent the spread of contamination. If there are airborne radioactivity potentials, turn off all room ventilation.
- SHIELD THE SOURCE: If possible, and if necessary ( $> 5$  mr/hr at 3 feet), the spill should be shielded, but only if it can be done without significantly increasing your radiation exposure.
- CLOSE THE ROOM: Leave the room and lock the doors to prevent entry.
- REPORT TO RSO: Notify the Radiation Safety Office (RSO) immediately. During normal working hours, call 540-231-5364. If no one answers, immediately call the Virginia Tech Police at 911. After normal working hours, call the Virginia Tech Police at 911 and tell the dispatcher there is a radiation emergency.
- PERSONNEL DECONTAMINATION: Remove contaminated clothing and store for further evaluation by the RSO. If the spill is on the skin, flush thoroughly and then wash with mild soap and lukewarm water.

## **Posting Emergency Procedures**

- The emergency telephone numbers and laboratory line of authority should be given to everyone who works in the lab.
- The information in Appendix 2 should be posted next to every telephone in the lab.

- The information in Appendix 3 is to be posted outside the entrances to all laboratories containing radioactive materials.

### ***Emergency Notification Steps***

- The Virginia Tech Police dispatcher will notify Radiation Safety personnel according to a priority list.
- Virginia Tech Police officers will go to the scene of the emergency. They will, under the guidance of Radiation Safety personnel, provide such assistance as required to protect the public, and allow efficient corrective actions to be taken.
- The following University officials must be notified after steps have been taken to obtain emergency assistance by person in charge on the scene.
  - Department Head (or Responsible Unit Director for non-academic units)
  - Building Warden (when needed)
  - Other University officials will be notified by the above, as considered appropriate.
- The VDH will be notified by the RSO of incidents that cause or threaten to cause:
  - at least 25 rem total effective dose equivalent, contact immediately
  - at least 75 rem eye dose, contact immediately
  - at least 250 rads skin or extremity dose, contact immediately
  - at least 5 times the annual limit of intake is released in 24 hours, contact immediately
  - in excess of 5 rem total effective dose equivalent, contact within 24 hours
  - in excess of 15 rem eye dose, contact within 24 hours
  - in excess of 50 rem skin or extremity dose, contact within 24 hours
  - in excess of 1 times the annual limit of intake is released in 24 hours, contact within 24 hours

As a follow-up to telephone reports, a facsimile of a written report will be sent to VDH. A final report will be sent to VDH within 30 days of the telephone report.

- A full report on all emergencies will be made available to the Radiation Safety Committee promptly so that corrective and/or disciplinary measures can be determined and implemented.

### **SECURITY OF RADIOACTIVE MATERIAL**

Radioactive material must be secured by locks except when in the presence of authorized or informed and responsible personnel or if quantities do not exceed the values tabulated in Appendix 4.

The RSO will report loss of radioactive material to the VDH at 800-468-0138 or 800-468-8892 after hours by telephone as follows:

- immediately after discovery of losses in a quantity of at least 1000 times the Appendix 4 values
- within 30 days after discovery of losses in a quantity of at least 10 times Appendix 4 values
- a follow-up written report will be sent to VDH within 30 days of the telephone report

## **LABORATORY DESIGN AND SET UP**

Appropriate laboratory facilities must be available to all users of radioactive material as described in this section.

### ***Work Areas***

Work areas must be:

- approved by the RSO
- well defined and easily identifiable
- segregated from other work
- able to accommodate scope of work performed
- non-porous surfaces

### ***Fume Hoods***

Fume hoods must be:

- approved by the RSO
- radioisotope-rated whenever possible
- properly certified and inspected by EHS

Additional specifications are as follows:

- The interior should be one-piece, seamless material, with coved corners free of joints, cracks or gaskets. The preferred material is stainless steel.
- Ducts should be stainless steel. Each hood should be ducted independently, directly to the roof.
- Blowers must be roof-mounted, spark-proof, explosion-proof units, sized by Facilities or Capital Design. Minimum flow must be 100 feet per minute (fpm) and maximum flow must be 150 fpm at permissible sash openings.
- A HEPA filter and/or activated charcoal filter must be used in the exhaust duct if the unit is to be heavily used for radioisotope work, as determined by the RSO.
- New units must have an air motion sensor and alarm to ensure proper air velocity and direction. Older units must have, as a minimum, a signal light to indicate that the motor is receiving power.
- Location of the hoods within a facility must be done in cooperation with EHS and Facilities or Capital Design personnel. Hoods must be located as much as possible in a draft-free, low-traffic area. It should not be necessary to pass a hood to escape from an area in case of fire, an accident involving radioactive contamination or other emergency.
- When a hood requires maintenance, a check for contamination must be done prior to any maintenance activities. EHS personnel must certify the hood is working properly before it is returned to service.

### ***Storage Areas***

Storage areas must be:

- approved by the RSO
- lockable and secure
- provide segregation in the event of multiple principal users

## **Ventilation**

Adequate ventilation (6 – 12 air changes per hour) must be provided.

## **POSTING AND LABELING**

Rooms, areas, and equipment where radioactive materials are used or stored must be clearly marked with appropriately worded and designated standard radiation signs. The majority of these will be supplied by the RSO. Laboratories must purchase “Caution-Radioactive Material” tape to label small equipment.

### **Posting requirements**

- The entrance to each laboratory will be posted with the following:
  - Caution – Radioactive Material sign
  - Food and Beverage Restrictions
  - Emergency Contacts (Appendix 2)
  - Any other signs deemed necessary by the RSO
- A central work area frequented by all workers will be posted with the following:
  - Notice To Employees (State Form RHF-12)
  - Emergency Procedures (Appendix 3)
  - General Laboratory Radiological Safety Rules and Procedures (Appendix 5)
  - Any other information deemed necessary by the RSO
- All designated food storage and consumption areas must be posted
- The RSO may exempt posting of areas or rooms:
  - where radioactive materials are used or stored in quantities less than those listed in Appendix 4, Room Posting section
  - where the radioactive material is
    - used in a CONTROLLED AREA
    - in use for less than 8 hours, and
    - is constantly attended during the period by a person trained in radiation safety, who takes the precautions necessary to prevent the exposure of individuals to radiation.
  - where a sealed source is present, but the dose rate at 30 cm from the housing does not exceed 5 mr/hr
- The RSO may require the following posting of areas and rooms:
  - Each Radiation area (areas in excess of 5 mr/hr) must be clearly marked with a standard radiation sign bearing the words: CAUTION -- RADIATION AREA.
  - Each High Radiation area must be clearly marked with a standard radiation sign with the words: CAUTION -- HIGH RADIATION AREA. The area must meet the following requirements:
    - a control device, upon entry, will reduce the level below 100 mr/hr, or
    - a control device will energize a visible or audible alarm, or
    - entry ways are locked except when controlled access is required
  - Each Airborne Radiation area must be clearly labeled with a standard radiation sign with the words: CAUTION -- AIRBORNE RADIOACTIVITY AREA.



### ***Labeling requirements***

- Each container of radioactive material shall be labeled with:
  - the words “caution radioactive material” and the radiation symbol
  - name of the isotope
  - quantity of activity
  - date of measurement of activity
- Exceptions:
  - when containers do not hold quantities greater than values listed in Appendix 4
  - when the containers are used intermittently in lab work with the user present

## **LABORATORY INSPECTIONS**

### ***Radiation Safety Office Audits***

Radiation Safety personnel will conduct announced or unannounced inspections of each active laboratory. Labs that use unsealed or sealed sources will be inspected at least annually.

Inspections will include:

- review of facility conditions
- contamination surveys (when appropriate)
- radiation surveys (when appropriate)
- records review (annually)
- inventory review (annually)
- follow-up inspections on identified contamination concerns

Recommendations will be made, in writing, to the Laboratory Authority. It is the responsibility of the Laboratory Authority to carry out the recommendations within 90 days.

Radiation Safety personnel will conduct leak testing on sealed sources in use every six months. If the results are 0.005 uCi or more, the source will be removed from service and VDH will be notified in writing within five days.

### ***Laboratory Self-Audit***

Laboratories using radioactive materials are encouraged to perform self-audits on a regular basis.

#### **Labs using at least 200 microcuries at any one time must conduct the following:**

Daily:

- contamination survey of the immediate work areas to be done at the end of the work day or at the completion of the day’s work (only on days that activity is used)
- documentation of results required (see Appendix 6 for limits)
- portable instrument surveys may be performed
- swipe surveys must be performed by tritium users

Weekly:

- comprehensive surveys of entire laboratory and areas adjacent to exit points
- portable instruments may be used to pinpoint areas of concern

- swipe surveys must be performed
- all results must be documented (see Appendix 6 for limits)

**Labs using less than 200 microcuries at any one time must conduct the following:**

Daily:

- contamination survey of the immediate work areas to be done at the end of the work day or at the completion of the day's work (only on days that activity is used)
- documentation of results required (see Appendix 6 for limits)
- portable instrument surveys may be performed
- swipe surveys must be performed by tritium users

Monthly:

- comprehensive surveys of entire laboratory and areas adjacent to exit points
- portable instruments may be used to pinpoint areas of concern
- swipe surveys must be performed
- all results must be documented (see Appendix 6 for limits)

**NOTE: Comprehensive surveys of entire laboratory and areas adjacent to exit points are required at least monthly even if no radioactive material is used.**

***Inactivation of Authorized Equipment or Areas***

When designated areas or equipment are no longer used with radioactive material or equipment will be removed from the laboratory for any reason:

- the laboratory must conduct a documented thorough survey for removable contamination (swipe survey) and fixed contamination (meter survey)
- any equipment or rooms released must meet the criteria found in Appendix 6

To release rooms, lab personnel must conduct required surveys, and the RSO must be contacted to arrange for a final release survey.

**SURVEY INSTRUMENTS**

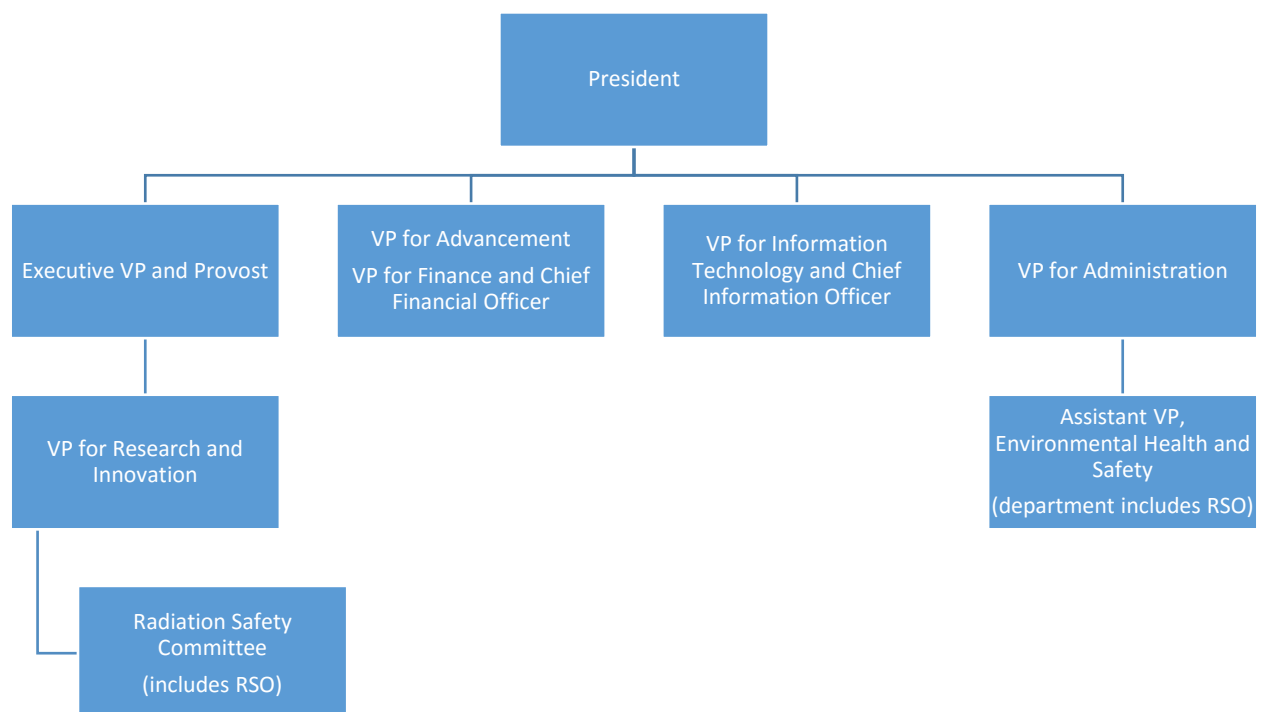
Laboratories using isotopes other than  $^3\text{H}$  must:

- be equipped with suitable portable radiation detection instruments or have access to an instrument from a nearby laboratory
- have instruments approved by the Radiation Safety Officer
- use instruments at least daily for checks on contamination levels
- have all portable survey instruments calibrated annually by the Radiation Safety Office
  - Portable survey instruments are calibrated annually and after any maintenance that may affect the calibration. This will be done by the Radiation Safety Office or qualified commercial firms. Instruments are calibrated using  $^{137}\text{Cs}$  reference standards and/or are calibrated electronically.
  - Each scale is calibrated at two points, located at approximately 25 percent and 75 percent of full scale. Acceptable calibration is within 10 percent of the calculated exposure or count rate. Response factors or graphs are used as necessary to interpret meter readings to within accepted tolerances.

- Other reference standards (e.g.  $^{14}\text{C}$ ,  $^{90}\text{Sr}$ ,  $^{129}\text{I}$ ,  $^{57}\text{Co}$ ) are used to determine efficiencies of detection. Multipliers are determined for use whenever the CPM to DPM conversion is needed. The multipliers result in a value that is within 10 percent of the calculated DPM of the reference standard.

## APPENDICES

### **APPENDIX 1: Organizational Chart**



APPENDIX 2: Emergency Procedures and Contact Persons

**Personnel Protection Always Takes Priority**

**EMERGENCY ACTIONS**

Minor Spills: Notify Coworkers  
Prevent the Spread  
Clean Up  
Survey  
Call RSO for Help

Major Spills: Clear the Area  
Prevent the Spread  
Shield the Source  
Close the Room  
Report to RSO  
Personnel Decontamination

**EMERGENCY CONTACTS**

Name	Telephone	
	Office	Home
Laboratory Authority _____		
Office Address _____		
Secondary Contact _____		
Office Address _____		
Other Contact _____		
Office Address _____		
Other Contact _____		
Office Address _____		

Emergency Telephone Numbers	8 am - 5 pm	After 5 pm or Weekends
Radiation Safety Office	(540)231-5364	911*
Hazardous Material Safety	(540)231-2982 or (540)231-8758	911*
Biological Safety	(540)231-5864 or (540)231-3361	911*
Virginia Tech Police/Rescue	911*	911*
Blacksburg Fire Department	911*	911*

**\*If using a cell phone to dial 911, remember to identify your location for the operator  
OFF-CAMPUS SITES SHOULD USE 911 FOR LOCAL EMERGENCY RESPONSE**

**APPENDIX 3: Emergency Contacts**

**In Case of Emergency Call 911  
EMERGENCY CONTACTS**

	Name	Office Address	Telephone	
			Office	Home
<b>Principal Investigator(s)</b>				
<b>Secondary Contact</b>				
<b>Other Contact</b>				

Emergency Telephone Numbers	8 am – 5 pm	After 5 pm, Weekends
<b>Radiation Safety</b>	231-5364	<b>911 *</b>
<b>Hazardous Material Safety</b>	231-2982 or 231-8758	
<b>Biological Safety</b>	231-5864 or 231-3361	
<b>VT Police/Rescue</b>	<b>911 *</b>	
<b>Blacksburg Fire Department</b>		

*\* If using a cell phone to dial 911, remember to identify your location for the operator*

**OFF-CAMPUS SITES SHOULD USE 911 FOR LOCAL EMERGENCY RESPONSE**

*use the non-emergency number, (540) 382-4343, for information and to contact VT support personnel as needed*

Facility-specific safety manual (e.g., Chemical Hygiene Plan, Biosafety Manual) is located:

Safety Data Sheets and Material Safety Data Sheets (SDS/MSDSs) are located:

[http://www.ehss.vt.edu/detail\\_pages/document\\_details.php?category\\_id=29&document\\_id=250](http://www.ehss.vt.edu/detail_pages/document_details.php?category_id=29&document_id=250)

Effective Date: \_\_\_\_\_

#### **APPENDIX 4: Limiting Values**

These are the limiting values for container labeling, room posting, security and classroom-use training.

<b>Radioisotope</b>	<b>Container Labeling Required (microCuries)</b>	<b>Room Posting Required (microCuries)</b>	<b>Security and Classroom-Use Training Required (microCuries)</b>
Americium-241	0.001	0.01	0.001
Cadmium-109	1	10	1
Calcium-45	100	1,000	100
Californium-252	0.01	0.1	0.01
Carbon-14	100	1,000	100
Cesium-137	10	100	10
Chlorine-36	10	100	10
Chromium-51	1,000	10,000	1,000
Cobalt-57	100	1,000	100
Cobalt-60	1	10	1
Hydrogen-3	1,000	10,000	1,000
Iodine-125	1	10	1
Iodine-131	1	10	1
Iron-55	100	1,000	100
Iron-59	10	100	10
Manganese-54	100	1,000	100
Mercury-203	100	1,000	100
Molybdenum-99	100	1,000	100
Nickel-63	100	1,000	100
Phosphorus-32	10	100	10
Phosphorus-33	100	1,000	100
Plutonium-238	0.001	0.01	0.001
Plutonium-239	0.001	0.01	0.001
Sodium-22	10	100	10
Strontium-90	0.1	1	0.1
Sulfur-35	100	1,000	100
Technetium-99m	1,000	10,000	1,000
Thorium (natural)	100	1,000	100
Uranium (natural)	100	1,000	100
Zinc-65	10	100	10

## **APPENDIX 5: General Laboratory Radiological Safety Rules and Procedures**

1. High standards of cleanliness and good housekeeping must be maintained in all laboratories where radioactive material is present.
2. Eating, drinking, smoking or applying cosmetics are not permitted in areas where radioactive materials are used or stored.
3. University housekeeping personnel must clean only those areas designated by the Laboratory Authority. The users or their qualified laboratory personnel shall be responsible for the remainder of the housecleaning.
4. At least one preliminary run using appropriate test materials is recommended for new procedures and new personnel to test the effectiveness of procedures and equipment.
5. Radioactive solutions must not be pipetted by mouth.
6. All work must be performed on surfaces protected by plastic-backed absorbent paper in order to minimize contamination.
7. All containers of radioactive material must be properly labeled. (See *Posting and Labeling, Radioactive Material Safety Program*).
8. When radioactive material is used in a volatile or gaseous form, or in such a way that aerosols could be readily dispersed, the work must be performed in a manner intended to minimize the airborne contamination.
9. When work with radioactive materials is performed in a fume hood, the hood should be manufacturer-designated for radioisotope use. The sash opening should be minimized (less than 18 inches). Any equipment in the hood and work done in the hood should be as far back from the opening as possible.
10. It is the responsibility of the Laboratory Authority to ensure that all personnel under their supervision have read and are trained on the procedures specified in the *Radioactive Material Safety Program*. This document is available on line at <http://www.ehss.vt.edu/>.
11. All persons designated by the RSO to wear personnel monitoring badges must wear these devices when they work with or near radioactive material that requires monitoring.
12. Gloves are required when handling any radioactive material (except sealed sources). Other appropriate protective clothing and equipment may be required dependent on the procedure being used.
13. Radioisotopes must be used in such a manner that radiation exposure rates to personnel are kept as small as possible. The use of appropriately designed shields will minimize exposure.
14. Long-handled forceps, beaker tongs, etc. should be used routinely when handling radioactive material that emits high levels of radiation in order to increase distance between material and personnel.
15. All injuries possibly involving radioactive material, no matter how slight, should be monitored to determine if the wound is contaminated. Special protection is required to prevent the entry of radioactive material into the body through wounds. The RSO must be notified and will evaluate each situation.
16. All equipment that is suspected to have come in contact with loose radioactive material must be considered potentially contaminated. An authorized user must monitor the equipment for contamination before the equipment can be removed from the laboratory.
17. The use of biodegradable cocktails (e.g. alkyl benzene base) for liquid scintillation counting is strongly encouraged because of increased personnel safety.



18. When use of a facility or storage area is to be terminated, the Radiation Safety Office must be notified. See *Inactivation of Authorized Equipment and Areas, Radioactive Material Safety Program*.

**APPENDIX 6: Removable and Fixed Contamination Limits**

The table below provides contamination limits for various locations. Wipe testing assesses removable contamination. Fixed contamination is assessed by portable survey instrument use. Fixed contamination levels must be measured at a distance of no more than 1 cm. Correction factors must be used to convert dpm/probe surface area measurements to dpm/100 cm<sup>2</sup> measurements as follows:

- Pancake GM-probe ..... 6.5 X dpm = dpm /100 cm<sup>2</sup>
- Thin end window GM-probe ..... 15.6 X dpm = dpm /100 cm<sup>2</sup>
- Low energy gamma scintillation-probe... 20.0 X dpm = dpm /100 cm<sup>2</sup>

**CONTAMINATION LIMITS**

<b>Location</b>	<b>Contamination Type</b>	<b>Gross Beta, Gamma</b>	<b>Alpha</b>
General areas	Removable	220 dpm/100 cm <sup>2</sup> *	22 dpm/100 cm <sup>2</sup>
	Fixed	5,000 dpm/100 cm <sup>2</sup>	Non Detectable
Skin and Personal Clothing	Removable	220 dpm/100 cm <sup>2</sup>	22 dpm/100 cm <sup>2</sup>
	Fixed	220 dpm/100 cm <sup>2</sup>	Non Detectable
Contamination Control areas	Removable	2,200 dpm/100 cm <sup>2</sup>	220 dpm/100 cm <sup>2</sup>
	Fixed	50,000 dpm/100 cm <sup>2</sup>	500 dpm/100 cm <sup>2</sup>
Anti-Contamination Clothing	Removable	220 dpm/100 cm <sup>2</sup>	22 dpm/100 cm <sup>2</sup>
	Fixed	5,000 dpm/100 cm <sup>2</sup>	Non Detectable
Equipment, Tools, etc.	Removable	2,200 dpm/100 cm <sup>2</sup>	220 dpm/100 cm <sup>2</sup>
	Fixed	50,000 dpm/100 cm <sup>2</sup>	5,000 dpm/100 cm <sup>2</sup>

\*The VTH and EMC nuclear medicine areas use a clean limit of 2,000 dpm/100 cm<sup>2</sup> only for <sup>99m</sup>Tc