Radiation Safety Manual

Issued by
WFUHS General Radiation Safety Committee
EH&S Radiation Safety

Effective Date: November 2016

FOREWORD

The North Carolina Radiation Protection Section (NCRPS), Radioactive Materials Branch has issued a broad scope medical license (No. 034-0158-1) to Wake Forest University Health Sciences (WFUHS) and a broad scope academic license (No. 034-0215-1) to Wake Forest University (WFU) for receipt, possession, use, transfer, storage and disposal of radioactive materials for non-human research and educational purposes.

This manual contains policies and procedures essential in conducting an effective radiation safety program; it was written for Principal Investigators (PIs) and Radiation Workers using radioisotopes in non-human research.

All personnel handling radioactive materials for non-human research must be familiar with the contents of this manual; failure to comply is a violation of license conditions. This may result in loss of privileges to work with radioactive materials or other disciplinary action.

This manual is available in print, .pdf format to maintain on a laboratory computer and this link to the EH&S SharePoint site:

http://ishare.wakehealth.edu/ehs/RadiationSafety/Documents/Forms/AllItems.aspx

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Environmental Health & Safety
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SECTION 1: ORGANIZATION & RESPONSIBILITIES

The radiation safety program ensures that research with radioactive materials protects and minimizes risks to health, safety, and property. Fulfillment of this purpose is consistent with the educational and research goals of WFUHS and WFU.

This manual sets forth the policies, organization, operating procedures and standards of conduct within the Wake Forest University Health Sciences radiation safety program. Furthermore, it serves as a guide for individuals who have the authority to use radioactive materials in compliance with university policy, conditions stipulated in both broad scope licenses as well as applicable local, state and federal regulations. This manual only addresses the use of radioactive materials for non-human research.

This manual must be made available to all research personnel; it should be kept in the laboratory where radioactive materials are used, along with all other required radiation safety records.

All persons using radioactive materials must understand and comply with the provisions in this manual.

GENERAL RADIATION SAFETY COMMITTEE

In accordance with 10A NCAC 15.0324, the General Radiation Safety Committee (GRSC) advises the Dean of the School of Medicine on all matters related to radiation safety and establishes such policies and procedures as it may deem appropriate to ensure an adequate radiation safety program.

Appointed by the Dean, GRSC membership consists of a Chair, a representative of Administration, faculty members and the Radiation Safety Officer (RSO) experienced in the use of radionuclides and in protection against ionizing radiation. Members are appointed each July for three-year terms. The list of current GRSC members is maintained by EH&S Radiation Safety.

The GRSC meets at least semi-annually; agenda and meeting is presented in PowerPoint format. Minutes are maintained in EH&S Radiation Safety.

The GRSC has the ultimate responsibility for the use of radioactive material at WFUHS and WFU. It shall set policy and establish rules to be carried out by the RSO. It shall receive and review all pertinent reports and records of EH&S Radiation Safety and shall keep and maintain a record of all its transactions and reports. The GRSC shall consider the liabilities of WFUHS and WFU in all hazardous activities involving radionuclides.

RADIATION SAFETY OFFICER (RSO)

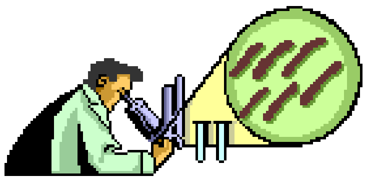
In accordance with Department of Energy regulations (10 CFR 35.24): A licensee shall provide the Radiation Safety Officer sufficient authority, organizational freedom, time, resources, and management prerogative, to identify radiation safety problems; initiate, recommend, or provide corrective actions; and verify implementation of corrective actions. The RSO is responsible for the daily operations of the radiation safety program, serves as a member of the GRSC and refers matters that require its review and approval.

The RSO has the authority to immediately terminate any unsafe practice or work activity without prior coordination with the GRSC or Administration. This authority includes unhampered access to all research projects utilizing radioactive materials or radiation. The RSO also has the authority to suspend or cease operations that are not in compliance with radiation safety regulations or license conditions.

ENVIRONMENTAL HEALTH & SAFETY (EH&S) – RADIATION SAFETY

EH&S provides radiation safety services for WFUHS and WFU; these include (but are not limited to) oversight and administration of the personnel monitoring program, laboratory audits, package receipts and delivery, radioactive waste management, response to any accidents/incidents involving ionizing radiation, license renewal and amendment, and radiation safety training.

Questions regarding the radiation safety program should be directed to the RSO at 716-1202, Monday - Friday, 8 am to 5 pm. After normal working hours, contact Security at 716-3305.



PRINCIPAL INVESTIGATOR (PI)

Defined as a faculty member at WFUHS or WFU who has submitted an application to EH&S Radiation Safety and been approved by the GRSC to use radioactive materials. PI is personally responsible for compliance with radiation safety policies and government regulations as they pertain to the authorized use of radioactive materials. Specific responsibilities include (but are not limited to):

1. Maintaining current and accurate records of the receipt, possession, acquisition, transfer, use, and disposal of radioactive materials (these records must be maintained for at least three years). Inventory records are only required for radioisotopes which have a half-life greater than three days.
2. Submitting the yellow inventory card (if isotopes were received) to EH&S Radiation Safety by the 16th day of each month or by electronic means.
3. Responding to any written Notice of Violation issued by EH&S Radiation Safety within 24 hours or 10 days, whichever is required as determined by EH&S Radiation Safety Inspector.
4. Assuring that all radioactive materials are transported in such a manner to prevent contamination in the case of an incident; use closed unbreakable containers or secondary containment. Use shielded transport containers if moving materials other than H-3 or C-14.
5. Using appropriate shielding in all areas where radioactive materials, including waste, are stored (Lucite or Plexiglas for beta emitters; lead for gamma emitters).
6. Pre-packaging sharp and/or breakable solid waste items in approved puncture-resistant containers before addition to any solid waste container.
7. Requesting additional radionuclides or changes in possession limits in writing to the RSO.
8. Receiving approval from RSO prior to transferring radioactive materials to other PIs.
9. Consulting with RSO prior to shipping radioactive materials anywhere off campus to determine compliance with Department of Transportation regulations.
10. Disposing of all radioactive waste through EH&S Radiation Safety; there is no drain disposal ("hot sink") in individual laboratories.
11. Reporting promptly to the RSO (716-1202, pager 806-3183) any condition that may lead to unnecessary exposure to radiation or a violation of rules outlined in this manual.
12. Requiring any personnel who will handle radioactive materials to first receive radiation safety training conducted by the RSO or his designee; person or PI should contact RSO to set this up.
13. Maintaining all documentation regarding the PI's radiation safety program and making these records available for review by EH&S Radiation Safety.
14. Notifying the RSO of intent to leave WFUHS/WFU at least 60 days in advance. The PI is responsible for disposing of radioactive materials inventory through EH&S Radiation Safety and for performing a final survey (smear and GM, if applicable) to demonstrate all work areas are free of contamination. Results of this survey must be submitted to EH&S Radiation Safety.
15. Notifying the RSO prior to any changes in locations where radioactive materials are stored or used; do not use or store radioactive materials in these new locations until you receive approval from the RSO.
16. Continuing decontamination efforts until there is no removable contamination in the event of a spill or whenever lab surveys show the presence of removable contamination.
17. Performing weekly surveys of all use and storage areas each week that radioactive material is used in the laboratory; additional surveys may be performed.

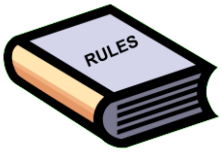
18. Documenting all survey results (including surveys following decontamination) and making these results available for review by EH&S Radiation Safety.
19. Notifying RSO immediately if you have lost or misplaced any radioactive material.
20. Instituting emergency action if EH&S Radiation Safety is not immediately available.
21. Notifying RSO of any non-employee or temporary worker who plans to work on a short-term basis in the laboratory to ensure documentation and appropriate level of training by RSO.

RADIATION WORKER

Any person who is approved by EH&S Radiation Safety to work with radioactive materials in a research setting (usually supervised by a Principal Investigator); their responsibilities are to:

1. Receive radiation safety training from RSO or his designee prior to using radioactive materials.
2. Keep radiation exposure As Low As Reasonably Achievable (ALARA).
3. Minimize time spent near sources of ionizing radiation.
4. Wear dosimeters (if provided by EH&S Radiation Safety) when working with radioactive materials.
5. Survey hands, shoes, body and clothing for contamination after using radioactive materials.
6. Use appropriate protective clothing (closed-toe shoes, long pants, appropriate gloves, safety glasses/goggles, lab coats, sleeve protectors, etc.) and automatic pipetting devices, fume hoods and shielding devices.
7. Never store food or drink in refrigerators or cold rooms used for radioactive materials.
8. Never eat, drink, smoke, apply cosmetics or remove contact lenses in areas where radioactive materials are used or stored.
9. Practice good housekeeping in the laboratory.
10. Check work areas for radioactive contamination after performing procedures which use radioactive materials.
11. Decontaminate all work areas where contamination levels are greater than twice background; re-survey the area after decontamination and document results.
12. Label, segregate and secure sources of radioactive materials, including waste.
13. Transport all radioactive materials in such a way to prevent contamination in the case of an accident. Use closed unbreakable containers or secondary containment. Use shielded transport containers if moving radioactive materials other than H-3 or C-14.
14. In the case of known or likely contamination to a person, both the person and clothing should be monitored. Clothing with contamination greater than twice background must remain in the laboratory for decay. The contaminated clothing may also be packaged and brought to the EH&S Waste Holding Area for decay. Decontaminate the skin immediately by rinsing with lukewarm (not hot, not cold) water; notify EH&S Radiation Safety immediately at 716-1202.
15. Report promptly to laboratory supervisor or RSO any condition that may lead to unnecessary exposure to radiation or a violation of the rules outlined in this manual.
16. Notify RSO immediately if you have lost or misplaced any radioactive material.
17. Report any spill or accident involving millicurie quantities of radioactive materials immediately to EH&S Radiation Safety.

SECTION 2: AUTHORIZATION & USE



Wake Forest University Health Sciences and North Carolina Baptist Hospital share a broad scope medical license for educational, research and clinical use of radioactive materials. Wake Forest University operates under a broad scope academic license for research using radioactive materials. These specific licenses have been issued by the North Carolina Department of Health and Human Services, Division of Health Service Regulation, Radiation Protection Section, Radioactive Materials Branch. These licenses specify and describe radionuclides, possession limits, locations for use and internal authorization procedures. EH&S Radiation Safety maintains control over these licenses.

Authorization must be obtained from the GRSC before any person may possess or use radioactive materials at WFUHS and WFU. No radionuclides may be received, used, or removed from these institutions without prior approval of the GRSC. The exception to this rule is the receipt, possession and use of radioimmunoassay (RIA) kits, which are subject to the provisions as contained in 10A NCAC 15.0314. RIA kits are used under General License No. 034-2085-0G and are defined as:

- iodine-125 in units not exceeding ten microcuries each;
- iodine-131 in units not exceeding ten microcuries each;
- carbon-14 in units not exceeding ten microcuries each;
- hydrogen-3 (tritium) in units not exceeding 50 microcuries each;
- iron-59 in units not exceeding 20 microcuries each;
- cobalt-57 in units not exceeding ten microcuries each;
- selenium-75 in units not exceeding ten microcuries each;
- mock iodine-125 reference or calibration sources in units not exceeding 0.05 microcuries of iodine-129 and 0.005 microcurie of americium-241 each.

RIA kits may be delivered to the end user by loading dock personnel; Principal Investigator must maintain records of receipt, use and disposal of RIA kits in accordance with Rule .0314 and manufacturer's instructions. Any questions regarding use of RIA kits should be directed to the RSO.

AUTHORIZATION TO USE RADIOACTIVE MATERIALS
Authorization to use radioactive materials is granted by the GRSC when the PI meets the minimum qualifications and requirements. Accordingly, each PI must apply for authorization by requesting and submitting an 'Application for Use of Radioactive Materials' to EH&S Radiation Safety. The completed application is forwarded for review to GRSC members. If necessary, on behalf of the GRSC, the RSO may request additional information from the applicant. The GRSC may also reject an application if it does not meet approval criteria.

Any potential PIs who have no previous experience handling radioisotopes must work under an active PI for a period of time; this supervised work must be documented. When the supervising PI determines that potential PI has an understanding of roles and responsibilities, supervising PI will send a letter to the RSO attesting to new PI's training.

<u>Application for Use of Radioactive Materials</u>
'Application for Use of Radioactive Materials' is posted on the EH&S Radiation Safety SharePoint site. The application has been designed to standardize the responses of applicants. It is preferred that submitted applications be typed or filled out online; contact the RSO for instructions.

<u>Applicant Qualifications and Requirements</u>
Principal Investigators must have training or practical experience in the principles of radiation safety, radiation detection and measurement and biological effects of ionizing radiation.

The possession limit of each radionuclide to be used must be identified in the application. All locations of use (including cold rooms and counting equipment rooms) and storage must be specified. A brief description of the experimental design for each radionuclide must also be included.

The GRSC reviews and evaluates these items in the application:

- Previous training and experience with radioactive materials;
- Description of experiments, including radionuclide, experimental design, approximate activity per experiment, estimated number of experiments per month, and type of laboratory animal (if applicable);
- Location of fume hood used for iodinations (if applicable);
- Description of radiation safety equipment to be used: protective clothing, fume hood, locations of absorbent paper, beta and/or gamma shielding, remote handling equipment, and secondary containment for liquids;
- Emergency procedures;
- Security of radioactive materials;
- Radiation detection equipment (survey meters and/or gamma counter, LSC);
- Location of records;
- Estimated amount of generated radioactive waste;
- Estimated amount of generated hazardous waste (if applicable); and
- List of Radiation Workers.

The PI is responsible for the orientation and any refresher training of all persons working under their authorization. Each employee must be familiar with elements of the radiation safety program.

Approval and Notification
Once the majority of the GRSC has approved the application, the RSO notifies the applicant in writing of the authorized radionuclides, possession limits, and locations of usage and storage. An EH&S Radiation Safety Inspector will be assigned to the PI for audits and support of research operations.

TERMINATION OF AUTHORIZATION
Principal Investigators are to notify the RSO at least 60 days prior to terminating their authorization due to retirement or leaving the institution. The PI is responsible for disposing of any remaining radioactive materials inventory through EH&S Radiation Safety and for performing a final smear survey/direct measurement (if other than H-3) to demonstrate that all work areas are free of contamination. Results of this final survey must be submitted to EH&S Radiation Safety.

The PI may use the 'Request for Amendment to Radioactive Materials Authorization' form or simply email the RSO of intent to leave or retire. If the form is used it may be submitted via facsimile (716-0588), campus mail or email.

Amendment Process
Amendments to the authorization must be requested in writing to the RSO and include sufficient detail to adequately evaluate the proposed change.

The 'Request for Amendment to Radioactive Materials Authorization' form may be submitted to the RSO via facsimile (716-0588), campus mail, or online. The PI also may simply email the RSO regarding specifics of the amendment request.

General Requirements for Laboratories
All laboratories using beta (other than H-3) and gamma emitters are required to have access to portable survey instruments capable of assessing ambient radiation levels and contamination levels. EH&S Radiation Safety conducts annual operational checks on these instruments.

Requirements for shielding or remote handling devices are dependent upon external radiation levels of the specific radionuclides and the amounts used by laboratory personnel.

In most cases, a normal laboratory with impervious lab bench tops and floors (meeting standard chemical laboratory requirements for ventilation, emergency showers, fire extinguishers, etc.) will be sufficient. Experiments involving volatile components, gases, or fumes require use of exhaust hoods.

USER SURVEYS
Principal Investigators are responsible for ensuring that weekly surveys (direct measurement with survey meter and smears) are conducted any week that radioactive materials are used in their lab. Surveys must be completed as soon as possible after being used for radioisotopes with half-lives

three days or less. Although more frequent checks may be performed, only the weekly surveys must be documented and available for review by EH&S Radiation Safety. If radioactive materials are not used during the week, no survey is required; however, it must be documented that no survey was performed because no radioactivity was used. The PI is not required to start keeping this documentation until radioactive material has been added to his/her inventory for the first time since approval.

Note: Once a PI has a zero inventory balance (i.e., no isotopes or waste) surveys will not need to be documented until the next receipt of radioisotopes (package or transfer). Once this receipt occurs documentation of weekly surveys must resume the same week.

- Ensure survey meter operational check is current (within last 12 months, check sticker)
- Batteries should be good; if not, replace with new batteries
- Remove protective cap/cover from probe
- Test survey meter’s response to a source of radiation (check source, isotope vial)
- Speaker should work, few clicks/second indicates detection of background radiation (bkg)
- Probe should not have a glove or plastic cover over detector (will give low errant readings)
- Measure bkg level in laboratory; normal bkg levels are ~20-60 counts per minute (cpm)
- Move probe 1-3” per second, survey ¼-½” from surface
- Keep eyes on probe, listen for increase in clicks
- Survey storage, work, waste areas as well as door handle, light switch, keyboard, etc.
- Contamination defined as >2x bkg
- Trust your survey meter readings! Any questions or concerns, contact RSO

<u>Method</u>
Weekly smear surveys are required for all isotopes used during the week, except for cyclotron-produced radioisotopes (F-18, O-15, C-11, etc.). In addition, weekly surveys with a portable meter are required for all isotopes, except H-3. Wipe an area of ~4” x 4” (~100 cm^2), count smears in liquid scintillation counter (first vial contains only scintillation fluid, no smear, to act as background); keep printout as proof of date & time of smears.

<u>Action Levels</u>
Areas where survey results are greater than twice background must be decontaminated. After decontamination the area must be re-surveyed and the results must be documented. Spills must be reported to EH&S Radiation Safety (refer to Section 6). Cleanup materials (paper towels, rags, etc.) must be disposed of as radioactive waste, not regular waste. Contact RSO with any questions.

<u>Records</u>
All weekly surveys must be documented. Smear results can be recorded in either cpm or dpm (if the isotope’s efficiency for the counter is known); records must include: date & name of person

conducting survey, survey location (building and room number), survey meter used, background radiation levels, radiation/contamination levels, corrective action(s), re-survey results.

Records must be maintained in the laboratory for at least three years and be available for review by EH&S Radiation Safety as well as state inspectors.

Summary of characteristics of common research isotopes; refer to Section 8 for more information:

Isotope	Emission	Energy (MeV)	Half-life	Max Range	Detection
^{3}H	β^-	0.0186	12.28 a	0.19” in air	LSC
^{14}C	β^-	0.156	5730 a	8.6” in air	Survey meter & LSC
^{32}P	β^-	1.709	14.29 d	20’ in air; 0.3” in H_2O	Survey meter
^{33}P	β^-	0.249	25.4 d	18” in air	Survey meter
^{35}S	β^-	0.167	87.4 d	9.6” in air	Survey meter
^{36}Cl	β^-	0.710	3.01×10^5 a	7’ in air; 0.1” in H_2O	Survey meter
^{45}Ca	β^-	0.257	163 d	19” in air	Survey meter
^{51}Cr	γ	0.320	27.7 d	N/A	Survey meter
^{59}Fe	$\beta^-\gamma$	1.565	44.6 a	45” in air	Survey meter
^{63}Ni	β^-	0.066	100 a	2” in air	Survey meter
^{125}I	γ	0.035	60.14 d	N/A	Survey meter w/NaI probe

RADIONUCLIDE USE IN ANIMALS

The use of radionuclides in animals requires review and approval from the Institutional Animal Care and Use Committee (IACUC) and the GRSC/RSO.

The PI must first be approved by the GRSC as a Principal Investigator. This approval allows the PI to possess and use specific radioactive materials in specific locations on campuses. For use of radioactive materials in animals, the PI must address animal care issues and make provisions for collection and storage of animal carcasses and associated waste.

For each animal protocol that includes radioactive materials, the PI must submit a protocol via eIACUC (online protocol submission web application). Within this protocol you are required to upload a ‘Hazardous Material’ form which outlines how you plan to use radioactive material in animals. This form will be reviewed and approved by the RSO or his designee to ensure that you are allowed to use the radioactive material listed in the protocol and that you are authorized for the locations listed.

Additional information regarding the use of animals in research is available in the ‘IACUC Manual of Policies’ and the ‘Animal Resources Program (ARP) Manual’ in the Office of Research. Specific instructions and recommendations will depend on the protocol, radionuclide(s), level of activity, frequency of use, number of animals and size of animal(s). The Animal Resources Program Operations Manager should be notified prior to actual use of any radioactive materials in live animals housed in the central animal facility.

LABORATORY AUDITS

EH&S Radiation Safety Inspectors audit active Principal Investigators at least three times each year. An audit will not be conducted if the PI has had a zero inventory balance since the last audit.

Audit includes a review of required postings, radiation safety related records, measurement of ambient radiation levels using portable survey instruments and measurement of removable contamination levels by smear surveys. The RSO presents laboratory audit results at GRSC meetings. Escalated enforcement action may be implemented for violations identified in the laboratories and research areas; the RSO will confer with the GRSC Chair to determine appropriate action. Documentation of the action will be maintained in the PI’s records.

These items are evaluated during audits:

- Materials used since last inspection
- Rooms posted as required (current "Notice to Employees" and Emergency Procedures)
- Adequate personnel monitoring/proper use & storage of dosimeters (if applicable)
- Routine use of gloves, lab coats, shielding and other appropriate protective equipment
- Signs/labels on source and waste containers as well as dedicated laboratory equipment
- Radiation Safety Manual available
- Absorbent paper on usage areas
- Inventory/disposal records current
- No eating, drinking or smoking in usage areas
- No food/drink in storage areas (refrigerators, etc.)
- Area survey records current
- Survey meter available, operational and source checked
- Purchase of new equipment (survey meter, liquid scintillation counter, gas chromatograph)
- Proper storage and adequate security of radioactive materials
- Radioisotopes used only in approved areas; any plans for lab to move or expand
- Bioassays completed (if applicable)
- All personnel handling isotopes have had documented training
- Any contamination detected

The PI will receive written notification of any items of noncompliance. During audit or after analyzing the smear survey data, EH&S Radiation Safety will immediately notify the laboratory if levels of contamination are greater than twice background. The PI or Radiation Worker must decontaminate the area, re-survey/re-wipe the area and document results at that time. If the contamination levels are still greater than twice background, operations must cease until the area is decontaminated and re-surveyed or efforts made to shield and reduce exposure.

<u>Notice of Radiation Safety Violation</u>
The EH&S Radiation Safety Inspector will provide a 'Notice of Radiation Safety Violation' to the PI if an item(s) of non-compliance is (are) observed during the quarterly laboratory audit. The PI will submit a written response to the RSO that describes the corrective action as well as actions to prevent recurrence. Failure to submit response in a timely fashion may result in revocation of the authorization to purchase radioactive materials, temporary suspension of authorization or termination of authorization (this may lead to denial of institution approval of grant applications).

Violation Codes:

A. The violation or observed hazardous condition(s) require(s) immediate attention. Please take corrective action and provide written response to EH&S Radiation Safety within the next 24 hours. Failure to act may result in temporary suspension of your authorization to use radioactive materials.
B. Please take corrective action and provide written response to EH&S Radiation Safety within 10 working days. Failure to act may result in revocation of your authorization to purchase radioactive materials until the response is received by EH&S Radiation Safety.
C. Corrective action was implemented during the audit.

<u>Posting of Notice of Radiation Safety Violation</u>
Principal Investigators are required to post within 24 hours any 'Notice of Radiation Safety Violation' issued by EH&S Radiation Safety during an audit. The Notice, along with the response from the PI, should be posted in the laboratory and must remain posted for 5 working days or until corrective action is implemented, whichever is longer.

<u>Repeat Violations</u>
If a repeat violation is observed within a twelve month period, the Principal Investigator's department chair will receive a copy of the audit results. If a third violation of the same item occurs within a twelve month period of the previous violation, the authorization will be suspended until the PI meets with the GRSC Chair and RSO to justify continued use of radioactive materials. The GRSC and Senior Dean will be notified of the results of this meeting.

General Radiation Safety Committee action may include (but is not limited to) re-training of laboratory employees, placement of the PI into a probationary status that will include increased frequency of EH&S Radiation Safety audits, limitation or suspension of the authorization, or termination of the authorization and removal of all radioactive materials by the RSO.

These are the most common violations noted during laboratory audits and their solutions:

Violation	Solution
Failure to perform or document wipe tests	Wipe tests must be performed at least weekly in labs using or storing isotopes; use pre-dated maps of survey areas and save LSC printouts with data
Radioactive material contamination in the laboratory	Use absorbent paper in trays and perform post-use surveys of work area and self
WFUHS Radiation Safety Manual or records not available or accessible in laboratory	Store in unique binder for ready identification and access; this manual is also available on-line
Personnel working with isotopes have not received documented training	All radiation workers must have documented training, contact RSO for next class; RSO maintains training records & certificates
Eating, drinking, smoking, applying cosmetics in the laboratory	To minimize possibility of ingesting radioactive material, food and drinks must be consumed in break areas only, not laboratory
Radioactive waste not properly stored	Solid and liquid wastes should be segregated and shielded, if applicable (e.g., P-32)
Radioactive waste improperly disposed of	Suspected or known radioactive waste must not be disposed of in regular trash; if in doubt, contact the RSO
Current "Notice To Employees" not posted	Required to be posted in conspicuous place; contact RSO for more copies if necessary
Survey meter is not operational, has dead batteries or is broken	Check batteries before using meter to ensure response to radiation; check cable for breaks or shorts; borrow meter from another lab to survey
"Caution-Radioactive Materials" not posted or labeled	Equipment potentially contaminated must be labeled to identify hazards; contact the RSO for tape or labels

WARNING SIGNS
Each area or room in which there is used or stored radioactive materials, must be posted with a conspicuous sign bearing the radiation symbol and the words "CAUTION RADIOACTIVE MATERIAL(S)." The signs must be magenta, purple or black on a yellow background.

This posting is required on every room that a PI has designated in their application and amendments. This sign is only removed by EH&S Radiation Safety when a PI terminates his/her authorization and it has been demonstrated that the room is free of contamination and nothing inside the room is posted as radioactive. The exception to this rule is for rooms located in the Animal Resource Program. These rooms are temporarily posted by a Principal Investigator while conducting animal studies. When finished the user will conduct a radiation survey and if there is no contamination then the sign is removed from the room. This survey must be documented along with the PI's survey records.

A current "Notice to Employees" must be posted in a conspicuous place in the laboratory; contact the RSO for a copy if one is not available.

SECTION 3: RADIATION EXPOSURE CONTROL

In accordance with 10A NCAC 15.1603(b): "The licensee shall use procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public and releases of radioactive materials in effluents to unrestricted areas that are as low as is reasonably achievable (ALARA)"

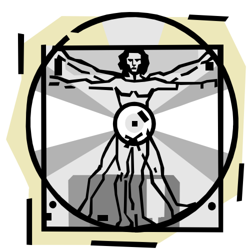
How do we meet ALARA standards?

- Train personnel and issue isotope-specific information (e.g., Nuclide Safety Data Sheets)
- Control & design of work area for radioisotopes
- Make use of principles of time, distance & shielding
- Develop & enforce good work practices involving radionuclides (training & audits)
- Conduct routine radiation surveys to monitor for contamination
- Monitor personnel for occupational exposure (not required in most instances for research)
- Administrative control & documentation of receipt, use, transfer & disposal of isotopes

CHARACTERISTICS OF RADIATION

The majority of isotopes used in research are beta particle emitters (e.g., H-3, C-14, P-32, S-35) and occasionally gamma ray emitters (e.g., Cr-51, I-125). This chart depicts characteristics of radiation emitted by radioactive materials:

Name	Symbol	Charge	Mass	Nature	Range (air)	Shielding
Alpha particle	α	+2	4	2 p + 2 n	Few cm	Paper
Beta particle	β- or β+	-1	0.00055	Electron	Few m	Al foil
Gamma ray	γ	0	0	Photon	Very long	Pb sheet



BIOLOGICAL EFFECTS OF RADIATION (SOURCE: NRC)

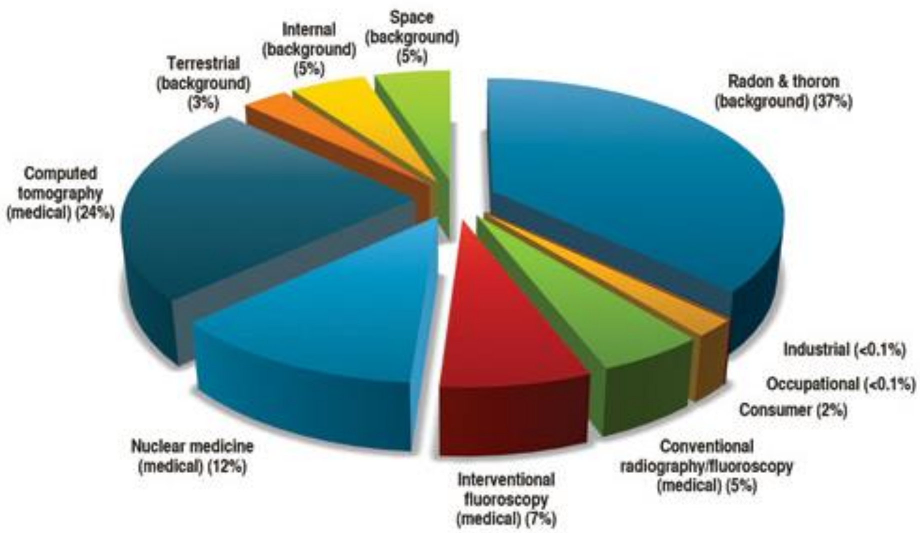
Radiation is all around us. It is in our environment and has been since the Earth was formed. As a result, life has evolved in the presence of significant levels of ionizing radiation. It comes from outer space (cosmic), the ground (terrestrial) and even from within our own bodies. It is in the air we breathe, the food we eat, the water we drink and the materials used to build our homes.

Some foods such as bananas and Brazil nuts naturally contain higher levels of radiation. Brick and stone homes have higher radiation levels than homes made of other materials such as wood. The US Capitol, which is largely built of granite, contains more radiation than most homes. A lot of our exposure is due to radon, a gas from the Earth's crust that is present in the air we breathe.

This natural radiation that is always present is known as "background" radiation. Background levels can vary greatly from one location to the next. For example, Colorado, because of its altitude, has more cosmic radiation than the East or West Coast. It also has more terrestrial radiation from soils rich in naturally-occurring uranium. So people living in Colorado are exposed to more background radiation than residents of the coasts.

On average, a US resident receives an annual radiation exposure from natural sources of ~310 millirem. Radon and thoron gases account for two-thirds of this exposure; cosmic, terrestrial, and internal radiation account for the rest.

Man-made sources of radiation from medical, commercial and industrial activities contribute roughly 310 mrem more to our annual exposure. Computed tomography (CT) scans, which account for about 150 mrem, are among the largest of these sources. About another 150 mrem each year comes from other medical procedures. Some consumer products such as tobacco, fertilizer, welding rods, exit signs, luminous watch dials and smoke detectors contribute about 10 mrem per year. This graphic illustrates radiation sources that contribute to the average annual US radiation dose.



Natural and man-made radiation may come from different sources, but both affect us in the same way. The NRC and Agreement States do not regulate background radiation but they do require their licensees to limit exposure to members of the public to 100 mrem per year above background. Exposure to adults working with radioactive materials must be below 5,000 mrem per year.

We tend to think of the effects of radiation in terms of how it impacts living cells. For low levels of exposure, the biological effects are so small they may not be detected. The body is able to repair damage from radiation, chemicals and other hazards. Living cells exposed to radiation could repair themselves, leaving no damage; die and be replaced (much like millions of body cells do every day); or incorrectly repair themselves, resulting in a biophysical change.

The data on links between radiation exposure and cancer are mostly based on populations receiving high level exposures. Much of this information comes from survivors of the atomic bombs in Japan and people who have received radiation for medical tests and therapy. Cancers associated with high-dose exposure (greater than 50,000 mrem - 500 times the NRC limit to the public) include leukemia, breast, bladder, colon, liver, lung, esophagus, ovarian, multiple myeloma and stomach cancers.

The time between radiation exposure and the detection of cancer is known as the latent period; this can be many years. It is often not possible to tell exactly what causes any cancer. In fact, the National Cancer Institute says other chemical and physical hazards and lifestyle factors (e.g., smoking, alcohol consumption and diet) make significant contributions to many of these same diseases.

The data show high doses of radiation may cause cancers. But there are no data to establish a firm link between cancer and doses below about 10,000 mrem – 100 times the NRC limit.

Even so, the regulations assume any amount of radiation may pose some risk. They aim to minimize doses to radiation workers and the public. The international community bases standards for radiation protection on something called the linear, no-threshold (LNT) model. The idea is that risk increases as the dose increases. And there is no threshold below which radiation doses are safe. This model is a conservative basis for both international and NRC radiation dose standards. This means the model may overestimate risk.

High radiation doses (greater than 50,000 mrem) tend to kill cells. Low doses may damage or alter a cell's genetic code (DNA). High doses can kill so many cells that tissues and organs are damaged immediately. This in turn may cause a rapid body response often called "Acute Radiation Syndrome." The higher the radiation dose, the sooner the effects of radiation will appear, and the higher the probability of death.

Many atomic bomb survivors in 1945 and emergency workers at the 1986 Chernobyl nuclear power plant accident experienced this syndrome. Among plant workers and firefighters battling the fire at Chernobyl, 134 received high radiation doses (80,000 to 1,600,000 mrem) and suffered from acute radiation sickness. Of these, 28 died within the first three months from their radiation injuries. Two workers died within hours of the accident from non-radiological injuries.

Because radiation affects different people in different ways, it is not possible to say what dose is going to be fatal. However, experts believe that 50% of people would die within thirty days after receiving a dose of 350,000 to 500,000 mrem to the whole body, over a period ranging from a few minutes to a few hours. Health outcomes would vary depending on how healthy the person is before the exposure and the medical care they receive. If the exposure affects only parts of the body, such as the hands, effects will likely be more localized, such as skin burns.

Low doses spread out over a long period would not cause an immediate problem. The effects of doses less than 10,000 mrem over many years, if any, would occur at the cell level. Such changes may not be seen for many years or even decades after exposure.

Genetic effects and cancer are the primary health concerns from radiation exposure. Cancer would be about five times more likely than a genetic effect. Genetic effects might include still births, congenital abnormalities, decreased birth weight, and infant and childhood mortality. These effects can result from a mutation in the cells of an exposed person passed on to their offspring. These effects may appear in the direct offspring if the damaged genes are dominant or they may appear several generations later if the genes are recessive.

While scientists have observed genetic effects in lab animals given very high doses of radiation, no evidence of genetic effects has been seen in the children born to Japanese atomic bomb survivors. NRC regulations strictly limit the amount of radiation that can be emitted by a nuclear facility, such as a nuclear power plant. A 1991 study by the National Cancer Institute, "Cancer in Populations Living Near Nuclear Facilities," concluded that there was no increased risk of death from cancer for people living in counties adjacent to US nuclear facilities.

If you are interested in more detailed information concerning biological effects of radiation, please contact the RSO at 716-1202.

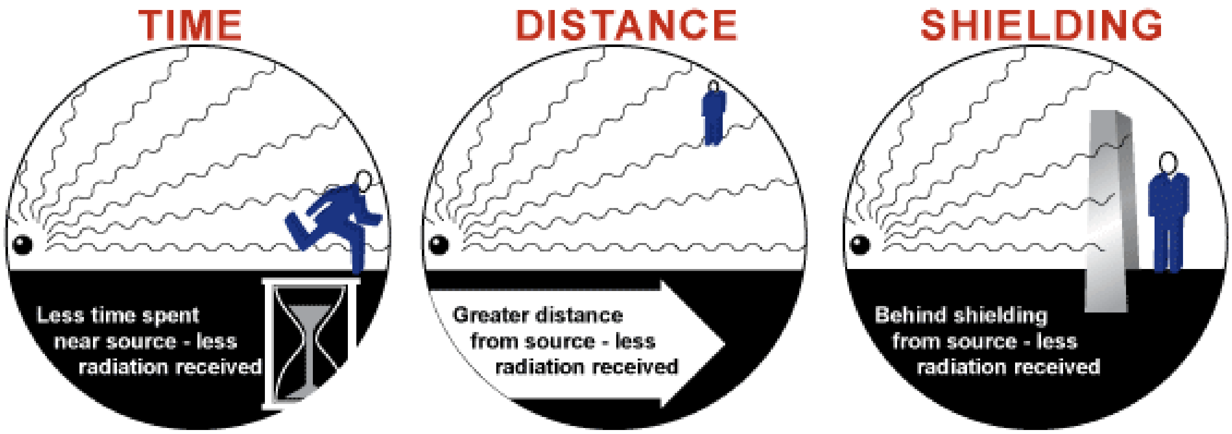
BASIC HANDLING REQUIREMENTS

Each person who uses radioactive materials is responsible for handling materials in such a way that personnel radiation exposures and levels of waste are as low as reasonably achievable. As described in the 'Application to Use Radioactive Materials,' the Principal Investigator may prescribe specific precautions to employees.

BASIC RADIATION SAFETY PRINCIPLES

Sources of radiation may be divided into two groups when considering physical principles for preventing or minimizing exposure: sources that are external to the body and those sources that may be internally deposited within the body. Internal deposition may be from inhalation, ingestion, absorption or injection of radionuclides.

The principles of reduced time, increased distance and increased shielding are always employed in any setting (research, clinical, industrial, etc.) to reduce one's exposure to ionizing radiation.



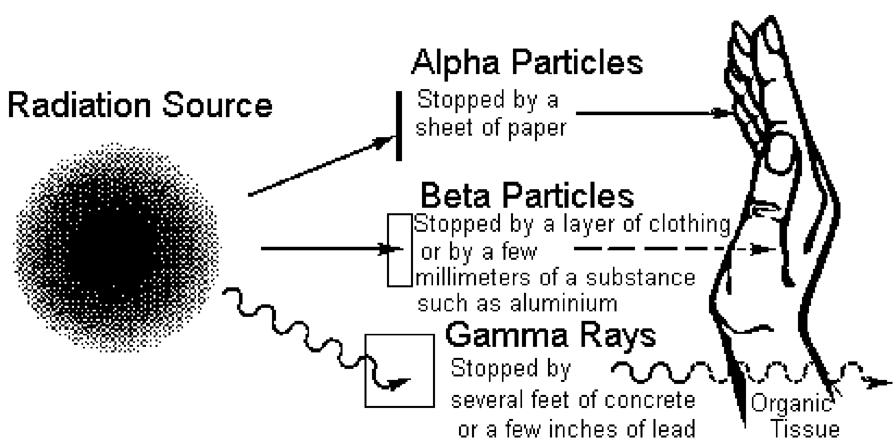
Control of External Exposure

External radiation exposure from a given radioactive source is controlled by the exposure time, distance from the source and appropriate shielding.

Decreasing the exposure time decreases the radiation dose proportionately. It is important to include “dry runs” with non-radioactive material for critical steps in preplanning all work that may involve substantial radiation exposure. Consideration of anticipated radiation dose is a fundamental aspect in preplanning work with radioactive materials.

Increasing the distance from the source is frequently the most effective and economical means to reduce radiation exposure from gamma rays and other highly penetrating radiations. The radiation exposure varies inversely with the square of the distance ($1/r^2$). For this reason, tongs or other long handled tools should always be used for manipulating radioactive preparations emitting significant levels of radiation. Radioactive sources should never be picked up with the fingertips; even low-level sources may be handled with short forceps that provide significant exposure reduction when compared with direct skin contact.

Shielding the source of radiation is necessary when the maximum distance and minimum time do not ensure a significantly low exposure to personnel. Shielding for gamma radiation is accomplished by interposing materials, preferably of high atomic number and high density, between the source and the area to be protected.



When high energy beta particles strike a material of high atomic number, the beta radiation produces penetrating x-rays called “bremsstrahlung” (German for “braking radiation”). The intensity of bremsstrahlung varies directly with the square of the beta energy and the atomic number of the shielding material. For this reason, low atomic number materials such as Lucite should be used for shielding beta radiation.

When working with energetic beta emitters, care must be taken to avoid exposing hands above open containers where the dose rate may be on the order of hundreds of rads per minute for commonly used quantities of beta emitters such as P-32 (~300 rad/h @ 1 cm from unshielded top of 1 mCi vial). When radioactive material emits both beta particles and gamma rays, shielding considerations will be controlled by the gamma radiation.

Lead for γ emitters

Lucite for β emitters

Appropriate shielding must be provided so that the radiation exposure rate is <2 mR/h in any controlled area.

Control of Internal Exposure

Time, distance and shielding are obviously not available for protection against radioactive materials internally incorporated within the body. Incorporation of radioactive material into the body is controlled by preventing the injection, inhalation, ingestion or absorption of such material. Accordingly, all significant quantities of unsealed radioactive materials must be used inside properly designed exhaust ventilated enclosures. Protective clothing (laboratory coats and gloves) should be worn when working with radioactive material. Contamination is defined as 'radioactive material not under your direct control and where you do not want it.' The only places your radioactive materials should be are in its original vial, your experimental media and eventually as radioactive waste properly stored and shielded, if applicable.

Preventing radioactive contamination assures reliable experimental results, avoids contaminating survey meters and cross-contamination of experiments.

REQUIREMENTS FOR LABELING RADIOACTIVE MATERIALS

All containers in which radioactive material is used or stored must be conspicuously labeled with a standard radiation warning label. The radiation symbol must be the standard three-bladed design and the label must be magenta, purple or black on a yellow background. Furthermore, the label must include the words "CAUTION - RADIOACTIVE MATERIAL(S)," the radionuclide, the amount of radioactivity and the date for which activity is estimated.

Secondary containers such as individual test tubes need not be labeled if they contain quantities less than those listed in the following table. However, a radioactive warning label should be affixed to items such as centrifuges that may become contaminated, particularly if the equipment is used by laboratory staff not working with radioactive materials. All radioactive waste storage containers must also be labeled.

QUANTITIES OF RADIOACTIVITY REQUIRING WARNING LABELS

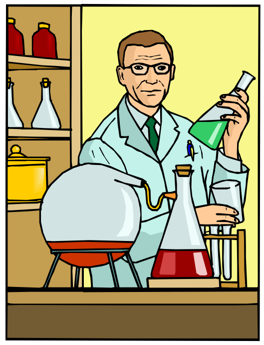
RADIONUCLIDE	MICROCURIES	RADIONUCLIDE	MICROCURIES
Hydrogen-3	1000	Cobalt-57	100
Carbon-11	1000	Iron-59	10
Carbon-14	100	Zinc-65	10
Fluorine-18	1000	Rubidium-86	100
Sodium-22	10	Technetium-99m	1000
Phosphorus-32	10	Indium-111	100
Phosphorus-33	100	Iodine-125	1
Sulfur-35	100	Iodine-131	1
Chlorine-36	10	Xenon-133	1000
Calcium-45	100	Cesium-137	10
Chromium-51	1000	Mercury-203	100

REGULATIONS REQUIRE LABELING OF EACH CONTAINER OF RADIOACTIVE MATERIALS EXCEEDING THE QUANTITIES SHOWN ABOVE. THE LABEL MUST BE DURABLE WITH A CLEARLY VISIBLE RADIATION WARNING SYMBOL AND THE WORDS "CAUTION - RADIOACTIVE MATERIAL(S)."

The label must provide sufficient information (radionuclide, quantity of radioactivity, date for which the activity is estimated) to permit individuals handling or using the containers, or working in the vicinity of the containers, to take precautions to avoid or minimize exposure.

SECURITY
10A NCAC 15.1622 states "The licensee shall secure from unauthorized removal or access sources of radiation that are stored in controlled or unrestricted areas; the licensee shall control and maintain constant surveillance of sources of radiation that are in a controlled or unrestricted area and that are not in storage."

It is recommended that laboratories, if possible, utilize refrigerators and/or freezers that lock in order to secure their isotopes. If this is not feasible, PI should make use of lockable shielded isotope containers that are affixed inside refrigerators and/or freezers as illustrated below:



LABORATORY RADIATION SAFETY RULES

1. All laboratory workers using radioactive materials must understand the nature of the hazard and receive radiation safety training by EH&S Radiation Safety prior to handling isotopes; contact the RSO by phone or email.
2. Wear disposable gloves, lab coats and appropriate clothing (closed-toe shoes, long pants, protective eyewear) at all times when handling radioactive materials.
3. Use lead for gamma emitters and Lucite shield for high-energy beta emitters.
4. Dispose of radioactive waste properly and often through EH&S Radiation Safety; do not allow it to accumulate within the lab.
5. Store radioactive materials in closed containers; contain materials within defined work area.
6. Transport all radioactive materials in such a way to prevent contamination in the case of an accident. Use closed unbreakable containers or secondary containment. Use shielded transport containers if moving materials other than H-3 or C-14.
7. Use radioactive material only on designated bench tops or designated work areas. Work surfaces should be covered with absorbent paper and spill trays should be used when working with significant liquid volumes of radioactive material.
8. Use an exhaust hood when working with volatile radioactive compounds (e.g., I-131, I-125 or H-3).
9. Never pipette radioactive solutions by mouth.
10. When starting a new procedure where radioactive materials will be used, perform a “practice run” without using the radioactive component to become familiar with the techniques employed. Plan ahead to minimize the amount of time that you are handling isotopes.
11. Do not eat, drink, smoke, store food, apply cosmetics or handle contact lenses in laboratories or any other area where radioactive materials are used or stored.
12. Perform and document weekly surveys of all areas where radioactive materials are used or stored. If no radioactive material is used during the week, no survey is required; however, you must document that no survey was performed because no radioactivity was used. Weekly smear surveys are required for all isotopes used during the week, except for cyclotron produced radioisotopes (F-18, O-15, C-11, etc.). Weekly surveys with a survey meter are required for all isotopes (except H-3, which isn’t detected via survey meter).
13. Decontaminate all contaminated surfaces (that are not covered with absorbent paper) to the extent that all contamination in excess of twice background is removed. Remove all contaminated absorbent pads. Place all contaminated cleaning items in proper radioactive waste containers.
14. Wash hands thoroughly upon leaving the laboratory, especially before eating, drinking, smoking, applying cosmetics or handling contact lenses.
15. Use remote handling equipment (i.e., tongs or forceps) when handling source vials or large amounts of gamma- or high energy beta-emitters. Distance yourself appropriately from any sources of ionizing radiation.
16. Monitor work, waste and storage areas frequently for contamination control.
17. Radioactive materials must be properly secured (locked in a storage container or room) when personnel are not present. Additionally, unauthorized personnel should not be allowed in areas where radioactive materials are used or stored unless accompanied by properly trained personnel. Maintain constant surveillance over your work area when handling isotopes.
18. All doors providing access to areas where radioactive materials are used must be posted with “Caution - Radioactive Material” signs. Additionally, all contaminated equipment or equipment containing radioactive material must be properly labeled with “Caution - Radioactive Material” tape.

SECTION 4: PROCUREMENT, RECEIPT, INVENTORY, TRANSFER & DISPOSAL

PROCUREMENT OF RADIOACTIVE MATERIALS

Principal Investigators or their Radiation Workers must order all radioactive materials on the current specific purchase requisition forms designated for this material. When the Purchasing Department receives an order, they contact EH&S Radiation Safety for approval prior to placing the order. This approval verifies that the PI is authorized to possess, use or store that radionuclide and quantity.

RECEIPT

Packages containing radioactive material are delivered by carrier to Shipping and Receiving, Monday through Friday from 8 am to 5 pm, unless pre-arranged with the RSO for other delivery times or locations. EH&S Radiation Safety signs for the packages in Shipping and Receiving and monitors them as required by 10A NCAC 15.1627. The packages are then delivered to the Principal Investigators, along with a blue card and green card.

Green card is presented to PI along with radioactive package for laboratory personnel to track its use.

RIA kits are exempt from monitoring for radiation and contamination and may be delivered directly to the end user by loading dock personnel.

The PI or designee must inspect the package and notify EH&S Radiation Safety immediately if any of the conditions are found:

- wrong radioactive material has been delivered;
- upon opening the package, there is evidence of leakage of radioactive material or any apparent break or compromise of the container; or
- it is determined that actual source activity differs from that listed on the shipping manifest or packing list.

PI or Radiation Worker must immediately notify RSO if any package containing radioactive material was not delivered by EH&S Radiation Safety staff; couriers are not to deliver packages directly to end user.

INVENTORY

In accordance with 10A NCAC 15.0115, licensees are to maintain records of the receipt, use, transfer and disposal of all radioactive materials. These records must be maintained for at least three years or until termination of the authorization, and must be available for review by EH&S Radiation Safety during audits as well as regulators.

PIs are required to keep specific records of each shipment on the 'Investigator Shipment Record.' This green card is provided by EH&S Radiation Safety with each package that is delivered to the laboratory. RIA kits and radioisotopes with a half-life less than three days are not to be included in the 'Inventory Log.' To simplify inventory, radioactive decay correction is not utilized (e.g, 5 mCi of P-32 remains 5 mCi throughout whole time of possession of isotope until disposal despite actual half-life of 14.29 days).

All radioactive waste must be disposed of through EH&S Radiation Safety; drain disposals are <u>not</u> allowed. With each disposal, the Radiation Worker must present the appropriate 'Investigator Shipment Record' card to EH&S Radiation Safety. A 'Disposal Number' for each batch of waste (along with the amount of radioactivity, date of disposal and remaining activity) is recorded on the green card.

By the 6th day of each month, PIs receive a yellow Inventory card from EH&S Radiation Safety only if their inventory has changed since the 6th day of the previous month. The PI completes the card with the quantity of each radionuclide in possession and then returns card to EH&S Radiation Safety by the 16th day of each month by campus mail or electronically. The inventory of each PI is compared to the records in the 'EH&S Radiation Safety Radioactive Inventory Log.' Discrepancies are investigated and resolved by EH&S Radiation Safety.

TRANSFER

Radioactive materials may be used or stored by PI in a variety of locations pending approval by the General Radiation Safety Committee. This necessitates the transfer of materials from one location to another. Furthermore, situations may require transfer of materials from one campus to another, one PI to another, or to another institution. In this case the PI must contact EH&S Radiation Safety at 716-1202 for further information and guidance.

Transportation throughout Main Campus

The transportation of radioactive materials between areas of authorized use (between laboratories or from labs to the Waste Holding Area for disposal) must be performed in such a manner as to minimize the potential for accidental contamination of hallways, elevators, etc. and personnel. To safely transport any radioactive materials:

- Use proper shielding: Lucite containers when transporting millicurie quantities of P-32; lead "pigs" when transporting millicurie amounts of gamma emitters
- Use shipping carton and packaging provided by manufacturer if transporting source vials
- If transporting bulk aqueous liquids, use unbreakable containers and surround the containers with a secondary containment system able to contain twice the volume of the inner containers. Make sure that all tops, lids, etc. are securely closed prior to transport
- Solid waste, carcasses or scintillation vials must be transported in securely sealed plastic bags.

Never leave radioactive materials unattended during transportation from one location to another.

Transportation between Campuses

EH&S Radiation Safety must be notified by the PI prior to transporting any radioactive material between campuses (such as Bowman Gray to Dean Research Building/BioTech Place). Proper containers and packaging must be used to meet Department of Transportation (DOT) regulations. Package surveys and wipe tests must be performed and shipping manifests completed by EH&S Radiation Safety.

Transfer between Principal Investigators on the Same Campus

Radioactive material may be transferred from one PI to another on the same campus. EH&S Radiation Safety must be notified in advance to ensure recipient PI is authorized to use the radionuclide and activity to be transferred, and that the activity is removed from the donor's inventory and added to the recipient's inventory.

Transfer between Principal Investigators at Different Campuses

Radioactive material may be transferred between PIs located on separate campuses (e.g., Bowman Gray to Dean Research Building/BioTech Place). EH&S Radiation Safety must be notified in advance to ensure recipient is authorized to receive the radionuclide and activity to be transferred; activity is removed from the donor's inventory and added to the recipient's inventory; and DOT regulations are met for proper containers, packaging, required surveys and completed shipping manifests.

Transfer to Other Institutions
Radioactive material may be transferred to another institution if it possesses a radioactive materials license issued by the US Nuclear Regulatory Commission or Agreement State. PI must notify EH&S Radiation Safety in advance to send radioactive material to another institution. The RSO will contact the RSO at the other institution to obtain shipping approval, a copy of the other institution's license and valid shipping address. Any packages offered for transport must comply with DOT regulations and be surveyed for radiation and contamination as well as proper marking, packaging and labeling.

Transfer from Other Institutions
Before radioactive material is transferred from another institution to a PI here, the PI must contact EH&S Radiation Safety to obtain approval to receive that particular radionuclide and activity. Additionally, the RSO at the other institution should contact RSO here for initial approval before the shipment is made. A confidential copy of our radioactive materials license should be on file at the other institution prior to any shipment of materials; all radioactive materials are to be shipped ONLY to this address:

Wake Forest University Health Sciences
Commons Loading Dock
C/O EH&S – Radiation Safety
Medical Center Boulevard
Winston-Salem, NC 27157-1023

ATTENTION: [Receiving PI's name] & Radiation Safety

NO other shipping addresses are to be used; under no circumstances should packages be sent directly to the receiving PI at their laboratory (PTCRC, Dean Research Building, BioTech Place, Friedberg Campus, etc.)

DISPOSAL
All radioactive materials must be disposed of through EH&S Radiation Safety; drain disposals are not allowed.

Waste collection:

- Bowman Gray Campus: Tuesdays and Fridays, 10 am - noon. Radioactive waste must be brought to the Waste Holding Area located on the "E" Level of the Commons Building (adjoining Medical School Shipping and Receiving).
- PTCRC: alternate Wednesdays, 1:30 - 2:30 pm.
- Friedberg campus: alternate Wednesdays, 10 - 11 am.
- Reynolda campus, Dean Research Building and BioTech Place: provided upon request.

Special collections (e.g., radioactive carcasses) may be arranged upon request calling EH&S Radiation Safety at 713-2855 and making an appointment.

WASTE SEGREGATION

Long-lived solids with H-3, C-14, Co-57 or any isotope with a half-life of greater than 90 days must be sealed in 4-6 mil plastic bags. Long-lived solid waste must contain no liquids including scintillation fluids, carcasses, tissue, blood or blood products. Source vials of long-lived isotopes (if not empty and dry) should be segregated from the rest of the solid waste and presented separately at disposal time.

Short-lived solids with P-32, P-33, I-125, I-131, Cr-51, S-35 or any isotope with a half-life of less than 90 days must be sealed in 4-6 mil plastic bags. All radioactive materials or radiation warning tape must be removed prior to disposal. I-125, I-131, P-33 and Cr-51 solid waste may be combined. P-32 and S-35 solid waste should be packaged separately. Source vials, whether dry or containing small volumes of liquid, may be placed in bags with short-lived solid waste provided all radioactive materials or radiation warning labels are removed or defaced. All bags must be securely sealed.

Aqueous liquids must be collected in tightly sealed break-resistant plastic containers having volumes of 1 to 2 liters (IV solution bottles are acceptable). A limited number of small containers for this purpose are kept in the waste holding area and available to the laboratories on a “first-come, first-serve” basis. If a Principal Investigator will routinely generate large volumes of aqueous liquids, it is recommended that he/she purchase 2 or 3 five-gallon plastic carboys for storing and transporting their aqueous radioactive liquids. In some cases, multiple isotopes may be combined in the same container with prior permission of EH&S Radiation Safety. All radioactive materials or radiation warning tape must be removed from aqueous liquid containers prior to disposal with the exception of any carboys purchased by the Principal Investigator.

Bulk organic liquids (other than scintillation fluids in vials) contaminated with radioactive material constitute a “mixed” waste and must be considered on a case-by-case basis with regards to disposal before being generated by the Principal Investigator. Historically, this type of waste material is prohibitively expensive to dispose of and researchers are strongly urged to avoid generating this type of material.

Scintillation vials containing radioactive scintillation media should be collected in 4-6 mil plastic bags in volumes not to exceed 0.5 cubic feet per bag. Scintillation vials containing H-3, C-14, and I-125 may be combined in the same bag. Scintillation vials containing S-35 or P-32 should be segregated and presented separately. All radioactive materials or radiation warning tape must be removed prior to disposal; all bags must be securely sealed.

Researchers are strongly encouraged to use aqueous-based “biosafe” scintillation fluids to reduce the levels of harmful vapors emitted by the older, organic cocktails in the laboratory environment.

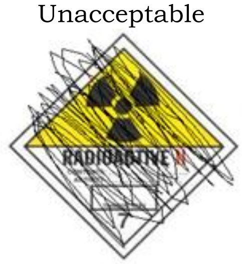
Carcasses should be double-bagged in 4-6 mil plastic bags and, when possible, frozen prior to disposal through EH&S Radiation Safety. Tissue, blood and blood products, and associated bedding are considered as “carcass.” All bags must be securely sealed and all radioactive materials or radiation warning tape must be removed prior to disposal.

Radioactive sharps including needles, scalpel blades, etc. must be placed in approved sharps disposal units. These containers are available from WFUHS Environmental Services; additional information on sharps disposal units is available from EH&S Biosafety.

All lead shipping containers must be segregated and presented separately from other waste. All radioactive materials or radiation warning labels must be removed or defaced prior to disposal; the words “Caution – Radioactive Material and trefoil must not be legible.

Unacceptable

Unacceptable



Acceptable

SECTION 5: PERSONNEL DOSIMETRY


Individuals may receive radiation dose from sources external to the body and from internally deposited radionuclides. Accordingly, both external and internal hazards must be considered when evaluating the engineering and administrative controls of radiation exposure.

In accordance with 10A NCAC 15.1614, our policy is to monitor those individuals expected to receive more than 10% of the applicable annual limits as well as declared pregnant workers.

OCCUPATIONAL EXPOSURE LIMITS
Exposure to occupationally-exposed workers must not exceed these annual limits:

Skin	50,000 mrem
Extremities	50,000 mrem
Any individual organ	50,000 mrem
Lens of eye	15,000 mrem
Whole body (internal + external)	5,000 mrem
Minors	10% of above limits
Fetal dose of declared pregnant worker	500 mrem during gestation period
General public	100 mrem
Unrestricted area	<2 mrem in any one hour

Whenever these limits have been reached, the individual will be required to avoid future work with radiation or radioactive materials until beginning of new calendar year.

Past monitoring of WFUHS research personnel is depicted below by department and average annual exposure (all below annual general public dose limit of 100 mrem):

Biochemistry: 40 mrem
Biology: 48 mrem
Cancer Biology: 19 mrem
Comprehensive Cancer Center: 32 mrem
Dermatology: 45 mrem
Gastroenterology: 28 mrem
Gerontology: 10 mrem
Hematology/Oncology: 48 mrem
Hypertension Research Center: 49 mrem
Infectious Diseases: 48 mrem
Microbiology/Immunology: 60 mrem
Pathology: 34 mrem
Pathology-Comparative Medicine: 61 mrem
Pediatrics-Medical Genetics: 31 mrem
Pediatrics: 40 mrem
Physiology/Pharmacology: 43 mrem
Rheumatology: 25 mrem

EXTERNAL RADIATION DOSIMETRY

Types of Dosimeters
Luxel® OSL dosimeters are currently used to monitor occupational whole body radiation exposure to betas, gammas, x-rays or neutrons. Thermoluminescent dosimeters (TLDs) may also be used to monitor radiation exposure to extremities. Electronic personal detectors (e.g., Thermo Scientific RadEye G) are also available, upon request, to monitor acute radiation exposure.

Issuing Dosimeters
Regulations require monitoring of individuals who may receive, in one year, more than 10% of the occupational dose limits. PIs and Radiation Workers should contact the RSO to see if dosimetry would be necessary for their research. Any females who work with radiation may choose to voluntarily declare, in writing, their pregnancy to receive a monthly fetal dosimeter.

Exchange of Dosimeters
Each department or group of employees has a coordinator who works with EH&S Radiation Safety. The individual user is responsible for exchanging the dosimeter(s) with the coordinator within the first five working days of the month. Timely exchange of dosimeters is critical for accurate dose assessment and up-to-date exposure records.

For anyone issued a dosimeter, whole body and ring dosimeters used for research purposes are exchanged quarterly. Depending on exposure levels, PET research personnel may exchange their dosimeters on a monthly or quarterly basis as determined by the RSO.

As technology improves, digital dosimeters not requiring exchange may be incorporated to replace current dosimeters.

Proper Use of Dosimeters
A dosimeter is to be worn only by the person to whom it is issued; it is not to be loaned to other employees or used to monitor work areas. Dosimeters for monitoring work areas are available upon request from EH&S Radiation Safety.

Dosimeters must be worn on the body at the location of highest potential exposure; in research laboratories, dosimeters should be worn on the torso.

Ring dosimeters must be worn if there is potential significant exposure to the hands. If only one ring is issued to the employee, the ring should be worn on the dominant hand with the TLD turned toward the palm. The dosimeter must be worn under gloves to protect it from contamination. Be careful when removing gloves for disposal that ring dosimeter is not caught inside glove.

If issued, dosimeters must be worn when working with or around any sources of ionizing radiation at WFUHS or WFU. If an employee here is also working with radiation at another institution, the RSO should be notified; the other institution should provide the employee with a dosimeter to monitor radiation exposure incurred in that facility.

Do not wear dosimeters while undergoing personal medical or dental x-rays. If an employee undergoes a diagnostic or therapeutic nuclear medicine procedure, the RSO must be notified. Occupational dose limits are not applicable in these instances.

Dosimeters may heat sensitive and should not be stored or left in high temperature areas (e.g., inside of automobiles on sunny days).

Obtaining Dosimeters
Employees may request dosimeters from EH&S Radiation Safety by submitting a completed 'Personnel Dosimeter and Radiation Exposure History Request' form; this includes the full name of the individual, Social Security number, date of birth, Principal Investigator, department and signature. EH&S Radiation Safety will review the request and determine if dosimetry is required, and if the employee has taken radiation safety training.

Lost Dosimeters
If an individual loses a dosimeter, the employee must notify EH&S Radiation Safety in order for a spare dosimeter to be issued for the remainder of the monitoring period. The individual must submit a 'Lost Dosimeter' form with comments regarding the radionuclides and quantities used by the employee prior to losing the dosimeter. This information will used by EH&S Radiation Safety to determine whether any special calculations must be performed to assess the individual's dose for that monitoring period.

Obtaining Records of Exposure

Upon written request to EH&S Radiation Safety, an individual may obtain a record of his/her radiation exposure and the results of any measurements, analyses or calculations of radioactive materials deposited within his/her body. The written request must include the name of the individual, Social Security number, date of birth, department where the individual worked and the dates of employment and signature.

Dosimeter results available from EH&S Radiation Safety include (if applicable) monthly, quarterly, year-to-date, and lifetime doses.

FETAL MONITORING

The dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, must not exceed 500 mrem. This includes both external exposure and the dose from any internally deposited radionuclides in the pregnant woman and the embryo/fetus. Furthermore, efforts must be made to avoid substantial variation above a uniform monthly occupational exposure rate to a declared pregnant woman.

If the dose to the embryo/fetus is found to have exceeded 450 mrem by the time the woman declares her pregnancy, the additional dose to the embryo/fetus must not exceed 50 mrem during the remainder of the pregnancy.

Employees may declare their pregnancy by submitting a completed “Declaration of Pregnancy” form. The Radiation Safety Officer or his designee will review the employee’s job description, responsibilities and any available dosimetry information to determine if additional radiation monitoring or safety precautions are needed. The employee may withdraw her declaration of pregnancy for any reason.

Determination of Embryo/Fetus Dose Prior to Declaration of Pregnancy

The embryo/fetus dose from the estimated conception date to the pregnancy declaration date must be determined by EH&S Radiation Safety. For a woman working in a research lab who has been issued a whole body dosimeter, its exposure will be used for this estimate. If the woman has been monitored for internal exposures, the results will also be included the estimate.

Embryo/Fetus Monitoring Device

After a pregnancy is declared and the RSO or his designee has determined that additional radiation monitoring is required, the RSO or his designee will issue the worker a fetal dosimeter to monitor the embryo/fetus dose. The fetal dosimeter must be worn on the declared pregnant worker’s waist and must be exchanged monthly. Records of dose to an embryo/fetus will be maintained with the records of dose to the declared pregnant worker.

GENERAL PUBLIC DOSE

The total effective dose equivalent to individual members of the public must not exceed 100 mrem in a year due to operations governed by the broad scope licenses. Furthermore, the external exposure to an individual in any unrestricted area must not exceed 2 mrem in any one hour.

These same limits apply to members of the public who have access to controlled areas.

ALARA LETTERS
EH&S Radiation Safety reviews dosimetry records not only for over-exposures but also for unusually high exposures for particular departments or work assignments.

Dose	ALARA I	ALARA II	Annual Limit
Whole body	200 mrem	300 mrem	5,000 mrem
Extremity	2,000 mrem	3,000 mrem	50,000 mrem
Lenses	600 mrem	900 mrem	15,000 mrem

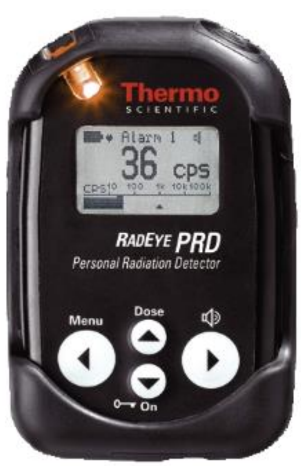
A letter is sent to those individuals who exceed ALARA I levels reminding them to keep exposures as low as reasonably achievable. A letter is sent to those individuals who exceed ALARA II levels and are required to respond with a possible explanation for the high dose. If applicable, the General Radiation Safety Committee reviews the list of employees who receive ALARA letters and their responses.

DOSIMETRY RECORDS
EH&S Radiation Safety maintains personnel dosimetry records for each employee who has been issued a dosimeter. An individual may obtain a copy of his/her records by submitting a written request to EH&S Radiation Safety; it must include their name, Social Security number, date of birth, department where the individual worked, dates of employment and signature. Results of any thyroid bioassays or tritium bioassays will be sent to each individual for his/her own personal records.

Prior Occupational Dose
Regulations require EH&S Radiation Safety to attempt to obtain records of lifetime cumulative dose for each employee issued a dosimeter. Individuals who have previously worked with radiation and wore dosimeters must provide EH&S Radiation Safety with the names and addresses of these prior employers. The "Personnel Dosimeter and Radiation Exposure History Request form" includes a location for the employee's signature which authorizes the former employers to release the individual's dose records to EH&S Radiation Safety.

Investigations of Overexposures
The RSO must notify the North Carolina Radiation Protection Section in cases of known or suspected exposure above the occupational dose limits. Upon completion of an investigation of the overexposure, a report will be provided to the individual involved.

DOSIMETERS FOR SUBCONTRACTORS, VISITORS, AND GUESTS
Principal Investigators and/or Radiation Workers who are responsible for the presence of outside contractors, visitors or guests in any laboratory where radioactive materials are used must notify EH&S Radiation Safety. Considering the general public dose limit to individuals in restricted or controlled areas, the RSO will determine whether and what personnel dosimetry is necessary. In these instances, an electronic personal radiation detector (pictured below) may be used to track acute radiation exposures.



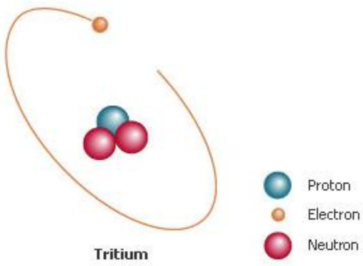
INTERNAL DOSIMETRY

When individuals use quantities of radioactive materials that present a chance for internal deposition, bioassays are required. Specific bioassay requirements have been established for personnel using radioactive iodine and tritium; EH&S Radiation Safety provides monitoring services.

Thyroid Bioassays

Thyroid monitoring must be provided within 24-72 hours for individuals working with >5 mCi of I-125 or I-131 in a single procedure or individuals working with >10 mCi I-125 or I-131 in multiple procedures over a period of one month.

EH&S Radiation Safety provides reminder notices when delivering packages of radioiodine to Principal Investigators with personnel who may meet these criteria; the individual user is responsible for contacting EH&S Radiation Safety to schedule thyroid monitoring.



Tritium Bioassays

Tritium urinalysis must be performed for individuals:

- Within one week following a single operation utilizing >100 mCi of H-3 in a non-contained from, other than metallic foil,
- Within 24 hours of a one-time use of 100 mCi of unencapsulated H-3, if internal deposition is suspected, or
- Monthly when quantities $\geq$100 mCi of unencapsulated H-3 are handled regularly.

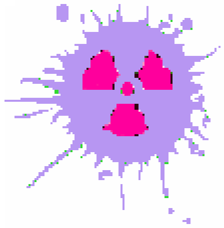
EH&S Radiation Safety provides reminder notices when delivering packages of tritium to Principal Investigators with personnel who may meet these criteria; the individual user is responsible for contacting EH&S Radiation Safety to schedule urinalysis monitoring.

Tritium urinalysis must be performed within 24 hours following an accident that results in contamination (e.g., skin cut, abrasion or injection). If such an incident occurs, notify EH&S Radiation Safety immediately at 716-1202 or page 806-3183.

SECTION 6: EMERGENCY PROCEDURES

Minor Spills (involving a few microcuries)

1. Cover spill with absorbent paper.
2. Notify persons in the area that a spill has occurred. If necessary, evacuate personnel to a safe distance in order to limit the chance of further spread of contamination.
3. Wear disposable gloves. Use tongs if available. Carefully fold the absorbent paper or pad. Perform a survey of the immediate area and decontaminate the area as necessary. Insert all contaminated items (including gloves and the absorbent paper or pad) into a plastic bag for disposal in a radioactive waste container.
4. Report the incident to EH&S Radiation Safety at 716-1202. A Radiation Safety Inspector may come to your laboratory to verify that the area has been decontaminated. The person responsible for the spill may be asked to submit a written report of the incident to the RSO.

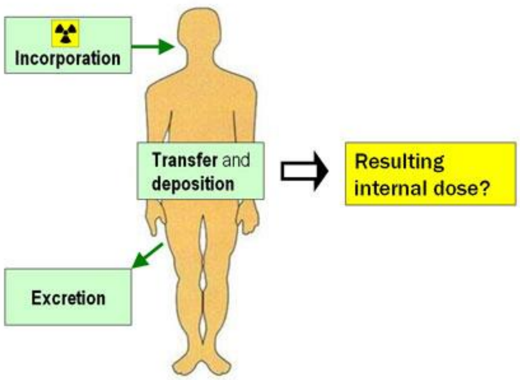


Major Spills (involving a few millicuries)

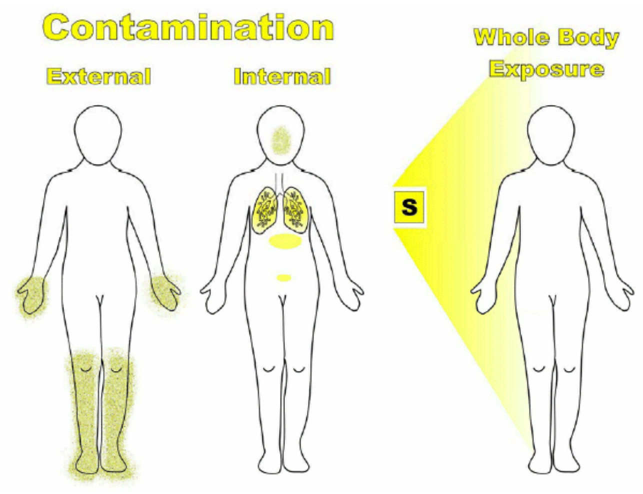
1. Notify all persons not involved in the spill to vacate the room.
2. Cover spill with absorbent towels or pads, but do NOT attempt to clean up.
3. Leave the room and prevent further entry.
4. Immediately notify EH&S Radiation Safety at 716-1202 for assistance with decontamination.
5. Stay in the immediate area and retain all involved persons in a safe area outside the room. EH&S Radiation Safety personnel may monitor individuals for potential contamination. The person responsible for the spill may be asked to submit a written report of the incident to the RSO.

Emergencies after 5 pm, weekends and holidays

1. Call the Operator at 716-9111.
2. Report that you have a radiation emergency.
3. Give the Operator your name, location and telephone number.
4. The operator will contact the appropriate individuals.



CONTAMINATION/EXPOSURE OF PERSONNEL



Serious Injury
There is no amount of radioactive contamination that would present a significant exposure hazard to attending medical personnel; prompt treatment for serious injuries should never be delayed.

1. Immediately provide emergency care and preserve vital functions.
2. Contact Security for transportation to the hospital: phone 716-9111.
3. Notify the RSO: phone 716-1202, pager 806-3183.
4. If possible, while waiting for transportation to the hospital, monitor the injured and remove any grossly contaminated clothing. Bag clothing and notify RSO.

Skin Contamination
External or skin contamination should be treated by washing with mild soap and copious amounts of lukewarm water (cold water will shrink pores and seal material, hot water will open pores to contaminate more skin). Be mindful of the chemical composition of the contaminant as well; this could pose more of a health issue than the radiation.

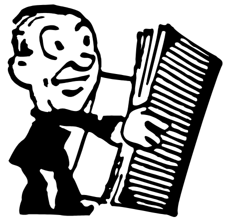
1. Avoid organic solvents or abrasive soaps that make the skin more permeable to the radioactive material.
2. Wash for approximately 2 to 3 minutes.
3. For contaminated hands, give special attention to areas between the fingers and around the fingernails.
4. Repeat no more than 3 or 4 times if contamination persists.
5. If this procedure fails, repeat washing using a soft hand brush.

Contaminated Wounds
When the skin is lacerated by contaminated glassware or injured by contaminated sharp instruments, immediately rinse the wounded area thoroughly under a stream of lukewarm water.

Ingestion of Radioactive Material
Immediately notify the Radiation Safety Officer at 716-1202 or pager at 806-3183 following ingestion or swallowing of radioactive material.

Exposure Only
Notify RSO immediately at 716-1202 with relevant information on source, location, etc.

SECTION 7: RADIATION GLOSSARY



Absorbed dose: The energy imparted by ionizing radiation per unit mass of irradiated material; units of absorbed dose are the rad and the gray (Gy); 100 rads = 1 Gy.

Activity: Rate of disintegration, transformation, or decay of radioactive material; English unit of activity is the curie (Ci), SI unit is the becquerel (Bq); 1 Ci = 3.7 x 10^{10} Bq.

ALARA: Acronym for "as low as is reasonably achievable") means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Annual Limit on Intake (ALI): Amount of a radionuclide that would result in a committed effective dose equivalent of 5 rems, or a committed dose equivalent of 50 rems to an organ or tissue. Refer to 10 CFR 20 Appendix B for nuclide specific values.

Area of use: A room, laboratory or suite in which radioactive materials is used; it may have one or more work areas.

Background radiation: Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout as it exists in the environment from the testing of nuclear explosive devices. Background radiation does not include radiation from source, byproduct, or special nuclear materials.

Becquerel (Bq): SI unit of radioactivity; 1 nuclear transformation per second (s^{-1}). See Curie.

Bioassay: The determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting), or by analysis and evaluation of materials excreted or removed from the human body.

Byproduct material: As defined by NRC regulations includes any radioactive material (except enriched uranium or plutonium) produced by a nuclear reactor. It also includes the tailings or wastes produced by the extraction or concentration of uranium or thorium or the fabrication of fuel for nuclear reactors. Additionally, it is any material that has been made radioactive through the use of a particle accelerator or any discrete source of radium-226 used for a commercial, medical, or research activity. In addition, the NRC, in consultation with the EPA, DOE, DHS and others, can designate as byproduct material any source of naturally-occurring radioactive material, other than source material, that it determines would pose a threat to public health and safety or the common defense and security of the United States.

CFR: Code of Federal Regulations.

Controlled area: An area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.

cpm: Counts per minute. Most radiation detectors display the number of events detected per unit of time. This can be converted to a measure of activity in dpm by dividing by the detection efficiency.

Curie (Ci): A unit of activity. 3.7 x 10^{10} nuclear transformations per second, 3.7 x 10^{10} becquerels, or 2.22 x 10^{12} nuclear transformations per minute. The term "nuclear transformations" is often replaced by the term "disintegrations."

DAC (Derived Air Concentration): The concentration of a given radionuclide that, if inhaled continuously during the work year, would cause a dose of 5 rem.

Declared pregnant woman: A woman who has voluntarily informed the licensee, in writing, of her pregnancy and the estimated date of conception; the declaration remains in effect until the declared pregnant woman withdraws the declaration in writing or is no longer pregnant.

Deep dose: The dose from external whole body exposure at a tissue depth of 1 cm.

Deterministic effect: Health effects, the severity of which varies with the dose and for which a threshold is believed to exist (e.g., radiation-induced cataract formation); also called a non-stochastic effect.

Dose or radiation dose: Generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined elsewhere in this glossary.

dpm: Disintegrations per minute; a measure of activity. See Curie.

Effective dose equivalent or effective dose: The sum of the products of the dose equivalent to each organ or tissue and multiplied by their respective tissue weighting factors, and then added to the external whole body dose.

Efficiency: measure of ability to detect radiation; defined as (measured cpm – background cpm) ÷ dpm; see Section 9.

Embryo/fetus: The developing human organism from conception until the time of birth.

Exposure: Being exposed to ionizing radiation or to radioactive material.

External dose: That portion of the dose equivalent received from radiation sources outside the body.

Extremity: Hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Gray (Gy): SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule/kilogram (100 rads).

GRSC: General Radiation Safety Committee.

High Radiation Area: An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

ICRP: International Commission on Radiological Protection.

Individual: Any human being.

Ionizing radiation: Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of separating a target atom into an electron and a positive ion. As used in this manual, radiation does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light.

Monitoring: The measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

NCRPS: North Carolina Radiation Protection Section. www.ncradiation.net

NCRP: National Council on Radiation Protection and Measurements. A non-profit corporation chartered by Congress to disseminate radiation protection guidance.

Non-stochastic effect: Obsolete term; see deterministic effect.

NRC: Nuclear Regulatory Commission; federal agency that formulates policies and regulations governing nuclear reactor and materials safety, issues orders to licensees, and adjudicates legal matters brought before it.

Occupational dose: Dose received by an individual in a restricted area or in the course of employment in which their assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.

Photon: A quantum of radiant energy. In this manual, the term usually means gamma rays or x-rays.

PO: Purchase Order.

Principal Investigator (PI): A faculty member at WFUHS or WFU who has submitted an application to EH&S Radiation Safety and has been approved by the GRSC to use radioactive materials.

Public dose: Dose received by a member of the public from exposure to radiation and to radioactive material released by a licensee, or to another source of radiation either within a licensee's controlled area or in unrestricted areas. It does not include occupational dose or doses received from background radiation, as a patient from medical practices, or from voluntary participation in medical research programs.

Quality Factor (Q): A modifying factor used to convert dose in rad to dose equivalent in rem; rem = rad x Q.

Type of Radiation	Q
x-rays, γ rays	1
β particles, e^-	1
Neutrons (<10 keV, >20 MeV)	5
Protons (>5 MeV)	5
Neutrons (100 keV – 2 MeV)	10
α particles, fission fragments	20

Rad: Special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram. 100 rads = 1 Gray.

Radiation area: An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Radiation Safety Inspector: An EH&S Radiation Safety staff member who has been assigned to a PI for the purpose of auditing the PI's labs.

Radiation Worker: An individual engaged in activities that are licensed by a regulatory agency and controlled by a licensee. Classification as a worker does not require an employer/employee relationship. Volunteers, students on clinical rotation, residents, staff, faculty, and visiting scientists and physicians whose duties include work with radiation or radioactive materials are considered workers.

Rem: The English unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor. For most forms of radiation, one rem is numerically equal to one roentgen or one rad. 100 rems = 1 Sievert.

Restricted area: An area, access to which is limited by the licensee for purpose of protecting individuals against undue risk from exposure to radiation and radioactive material.

Roentgen (R): The English unit of radiation exposure that liberates one esu of charge per cc of air. For most forms of radiation, one roentgen is numerically equal to one rem or one rad. Although considered obsolete, this term and its abbreviation are still commonly used.

RSO (Radiation Safety Officer): The individual responsible for managing the radiation safety or health physics program.

Secondary container: An additional container that holds the primary container of radioactive liquid to prevent contamination if the primary container has a leak. The secondary container should be big enough to hold twice the volume of the primary container.

Shallow dose: Applies to the external exposure of the skin of the whole body or the skin of an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeter.

Sievert (Sv): SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor. 1 Sv = 100 rems.

Stochastic effects: Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Survey: An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Tissue weighting factor (W_T): A weighting factor for an organ or tissue relating to the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly.

Organ or Tissue	**W_T**
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30*
Whole Body	1.00**

*0.30 results from 0.06 for each of 5 "remainder" organs (excluding the skin and the lens of the eye) that receive the highest doses.

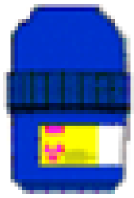
**For the purpose of weighting the external whole body dose (for adding it to the internal dose), a single weighting factor, W_T=1.0, has been specified. The use of other weighting factors for external exposure will be approved on a case-by-case basis until such time as specific guidance is issued.

Unrestricted area: An area, access to which is neither limited nor controlled by the licensee.

Work area: A portion of a room or laboratory suite where radioactive materials are stored or handled; usually a single countertop.

For more radiation-related definitions, refer to Section .0104 in the *North Carolina Regulations for Protection Against Radiation* or 10 CFR 20.1003; contact the RSO for more information.

SECTION 8: RADIOISOTOPE SUMMARY



Carbon-14 (C-14): half-life of 5,730 years; emits only beta particles with a maximum energy of 0.156 MeV and an average energy of 0.049 MeV. The beta particles from C-14 travel a maximum of ~2 feet in air. The principal radiation safety issue in the routine use of C-14 is that it cannot be easily monitored during use. Special precautions are needed to keep the work environment clean. The regular use of wipe testing is the only way to ensure that your work area is not contaminated. Contamination on the skin will not cause a significant dose; however, it could lead to the internal absorption of C-14. The annual limit of intake is 2 millicuries (mCi).

Calcium-45 (Ca-45): half-life of 162.7 days; emits only beta particles with a maximum energy of 0.254 MeV and an average energy of 0.076 MeV. The beta particles from Ca-45 travel a maximum of ~3 feet in air. The principal radiation safety issue in the routine use of Ca-45 is that it cannot be easily monitored during use. Special precautions are needed to keep the work environment clean. The regular use of wipe testing is the only way to ensure that your work area is not contaminated. Contamination on the skin will not cause a significant dose; however, it could lead to the internal absorption of Ca-45. The annual limit of intake is 800 microcuries (μCi) by inhalation and 2 mCi by ingestion.

Chlorine-36 (Cl-36): half-life of 300,000 years; emits beta particles with a maximum energy of 0.710 MeV and an average energy of 0.252 MeV. The beta particles from Cl-36 travel a maximum of ~8.5 feet in air. The principal radiation safety issue in the routine use of Cl-36 is that it can present a significant skin dose hazard. Special precautions are needed to prevent skin contamination with Cl-36 and keep the work environment clean. The regular use of a thin window Geiger-Mueller counter is the best way to ensure that your work area is not contaminated. Contamination could lead to the internal absorption of Cl-36. The annual limit of intake is 2 mCi by inhalation and 2 mCi by ingestion.

Chromium-51 (Cr-51): half-life of 27.7 days; emits photons with a maximum energy of 0.320 MeV. The major radiation safety concern associated with the use of Cr-51 is its radiation exposure from an unshielded vial. The dose rate at the surface of an unshielded vial containing 1 mCi of Cr-51 is ~1,800 millirems per hour (mR/h). The annual limits of intake are 50 mCi by inhalation and 40 mCi by ingestion.

Iron-59 (Fe-59): half-life of 44.6 days; emits beta particles with energies of 0.466 MeV (53.1%) and 0.273 MeV (45.2%) and gamma photons with energies of 1.292 MeV (43.2%), 1.099 MeV (56.5%) and 0.192 MeV (3.1%). The major radiation safety concern associated with the use of Fe-59 is its radiation exposure from an unshielded vial. The dose rate at the surface of an unshielded vial containing 1 mCi of Fe-59 is ~640 mR/h. The annual limits of intake are 300 μCi by inhalation and 800 μCi by ingestion.

Hydrogen-3 (H-3): commonly known as tritium; half-life of 12.3 years; emits only beta particles with a maximum energy of 0.019 MeV and an average energy of 0.0057 MeV. The beta particles from tritium travel a maximum of 6 mm in air. The principal radiation safety issue in the routine use of tritium is it cannot be easily monitored during use. Special precautions are needed to keep the work environment clean. The regular use of wipe testing is the only way to ensure that your work area is not contaminated. Skin contamination on the skin will not cause a significant dose; however, it could lead to the internal absorption of tritium. Many tritium-labeled compounds can readily penetrate gloves and skin. The annual limit of intake is 80 mCi in the form of water.

Iodine-125 (I-125): half-life of 60 days; emits gamma rays with a maximum energy of 0.035 MeV. The major radiation safety concerns with using I-125 are radiation exposure in air over an unshielded vial and inhalation/ingestion.

The dose rate at the opening of an unshielded vial containing 1 mCi of I-125 can be 1,400 mR/h. The annual limits of intake are 60 µCi by inhalation and 40 µCi by ingestion. Sodium iodide is known to be volatile in air and readily absorbed by the thyroid gland if inhaled or absorbed internally. Uncapped vials of I-125 and laboratory contamination with I-125 may potentially lead to uptake in the thyroid gland; extra precautions are necessary beyond the normal operating procedures for other radioisotopes. The absorption of 1 µCi of I-125 in the thyroid gland produces a thyroid dose of ~3.5 Rads.

Iodine-131 (I-131): half-life of 8.04 days; emits beta particles with a maximum energy of 0.606 MeV and gamma rays with a maximum energy of 0.364 MeV. The major radiation safety concerns with using I-131 are radiation exposures from an unshielded vial and inhalation/ingestion. The dose rate at the opening of an unshielded vial containing 1 mCi of I-131 can be 2,200 mR/h. The annual limits of intake are 50 µCi by inhalation and 30 µCi by ingestion. Sodium iodide is known to be volatile in air and readily absorbed by the thyroid gland if inhaled or absorbed internally. Uncapped vials of I-131 and laboratory contamination with I-131 may potentially lead to uptake in the thyroid gland and extra precautions are necessary beyond the normal operating procedures for other radioisotopes. The absorption of 1 µCi of I-131 in the thyroid gland produces a thyroid dose of ~5.3 Rads.

Sodium-24 (Na-24): half-life of 15.02 hours; emits beta particles with a maximum energy of 1.390 MeV and gamma photons with energies of 1.369 MeV and 2.754 MeV. The major radiation safety concern associated with the use of Na-24 is the radiation exposure from an unshielded vial: 1 mCi of Na-24 is ~18,400 mR/h. The annual limits of intake are 5,000 µCi by inhalation and 4,000 µCi by ingestion.

Phosphorus-32 (P-32): half-life of 14.3 days; emits beta particles with a maximum energy of 1.71 MeV. The beta particles travel a maximum of 20 feet in air. A 1 µCi drop of P-32 on 1 cm^2 area of skin produces an exposure rate of 2,000 mR/h. The dose rate at the opening of a vial containing 1 mCi of P-32 can be as high as 26,000 mR/h. Using orthophosphate can pose significant problems because of the large activity and high concentrations sometimes provided by suppliers. Experience has shown that laboratories using pre-labeled P-32 (dATP, etc.) in activities of 0.25 mCi and 0.5 mCi have had little or no safety problems. Using lower concentrations is very desirable in terms of routine handling. Most suppliers will provide lower concentrations if requested. The annual limits of intake for P-32 are 900 µCi by inhalation and 600 µCi by ingestion.

Phosphorus-33 (P-33): a lower energy alternative to P-32 as a phosphorus tracer; half-life of 25.4 days; emits only beta particles with a maximum energy of 0.249 MeV and an average energy of 0.083 MeV. The beta particles from P-33 travel a maximum of 46 cm in air. The major concern with using P-33 is that it cannot be easily monitored during use. Special precautions are needed to keep the work environment clean. The regular use of wipe testing is the only way to ensure that your work area is not contaminated. Skin contamination will not cause a significant dose; however, it could lead to the internal absorption of P-33. The annual limits of intake are 8 mCi by inhalation and 6 mCi by ingestion.

Sulfur-35 (S-35): half-life of 87.4 days; emits only beta particles with a maximum energy of 0.167 MeV and an average energy of 0.049 MeV. The beta particles from S-35 travel a maximum of 24 cm in air; properties are very similar to those of C-14. S-35 is difficult to distinguish from C-14. If both radioisotopes are used in the same laboratory, they should be kept separate to allow S-35 wastes to be decayed in storage due to its much shorter half-life. If unknown contamination is found in a laboratory using both radioisotopes, it should be treated as C-14. The major radiation safety concern in the routine use of S-35 is it cannot be easily monitored during use. Many Geiger Counters cannot detect the beta particles from S-35. Special precautions are needed to keep the work environment free of contamination. The regular use of wipe testing is the only way to ensure that your work area is not contaminated. Skin contamination will not cause a significant dose; however, it could lead to the internal absorption of S-35 if there are cuts in the skin. The annual limits of intake for S-35 are 20 mCi by inhalation and 10 mCi by ingestion. Radiolysis of S-35 labeled amino acids may lead to the release of S-35 labeled volatile impurities. Delivery vials should always be opened in the hood. The addition of buffers (stabilizers) will reduce, but not eliminate, the evolution of S-35 labeled volatile impurities.

SECTION 9: FACT SHEET FOR SURVEY METERS

Radiation survey instruments must function properly to both detect and measure radioactivity. If an instrument detects alpha, beta, gamma and X-ray radiation emissions can it be used to also accurately perform measurements? The answer may be yes <u>and</u> no. Instrument design, calibration, and proper field use are all very important factors in determining the response of an instrument. The two most commonly encountered survey instruments employ a ratemeter, which displays information in counts per minute (cpm) or millirem per hour (mR/h) connected to a Geiger-Mueller (G-M) type detector or probe. The two basic arrangements are the “hotdog” (cylindrical) and “pancake” (flat) probes. The “hotdog” probe may have either a circular end-window or an elongated side-window (beta window) which can be closed. Solid and liquid scintillation detectors are also available for more specialized uses.

G-M END-WINDOW DETECTORS

This probe may be calibrated to read out for exposure rate (mR/h) or count rate (cpm) measurements. It is more useful for cpm measurements (e.g., detecting and quantifying surface contamination levels). However, the typically small area of the probe window does restrict its utility for this purpose due to the limited detection efficiency, which can be achieved. Typical counting efficiencies:

- β emitters 100 – 300 keV: 2-5%
- β emitters 500 – 1700 kEv: 8-20%

G-M SIDE-WINDOW DETECTORS

This probe is best used for quantifying exposure rates (mR/h) for gamma and X-ray energies >60 keV by positioning the probe (with the window closed) perpendicular to the source. These probes are <u>not</u> designed for measuring surface contamination, evaluating swipes or personnel frisking. Although beta emitters with energies >200 keV can be detected through the open beta window, several factors make quantifying the detected activity very difficult.

G-M PANCAKE DETECTORS

This probe is best used for detection and measurement of surface contamination from beta emitters (e.g., C-14, S-35, Ca-45, P-32, etc.) and should be used with a ratemeter that reads out in cpm. Generally, the probe is positioned ~1 cm (~½ inch) above the surface and moved at 1-2 inches per second to detect contamination. Typical efficiencies are:

- C-14: 5%
- P-33: 15%
- Ca-45: 15%
- I-131: 25%
- P-32: >30%

Pancake probe is a good choice for detecting leakage radiation from x-ray machines, but should not be used to obtain exposure rate measurements in mR/h.

SCINTILLATION DETECTORS

Two common types of instruments rely on the detection of light scintillations produced in a detecting medium when energy from a charged particle or gamma radiation is imparted to it. Solid scintillators such as sodium iodide (NaI) 1”x1”x1 mm detectors coupled with a plastic scintillator can be used to measure beta and gamma radiations when connected with a ratemeter. The detectable energies are ~100-1700 keV for beta particles and 10-60 keV for gamma rays. Detection efficiencies of ~20% are possible for the 36 keV gamma ray of I-125 and 5-30% for the beta particles.

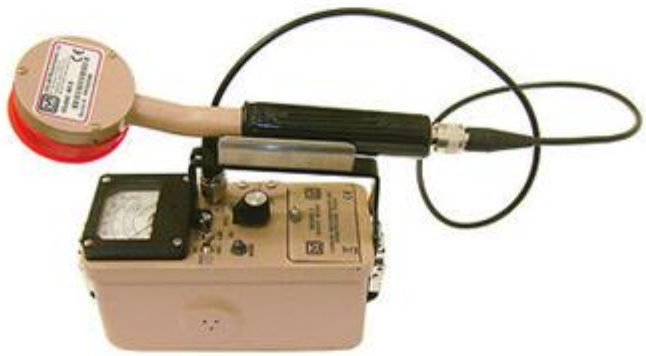
LIQUID SCINTILLATION COUNTER

This is practically the only method for detecting H-3 beta radiation and is used extensively for C-14, S-35, P-32, etc., but may be employed for a very large number of radioisotopes. This method is unique in that the sample is incorporated into the scintillator medium and counting efficiencies vary widely depending upon a number of sample specific factors such as color, degree of heterogeneity, chemical composition, and total volume.

Below are listed typical efficiencies and minimum detectable activities (MDA) which may be expected for three commonly used GM survey instruments. For the Ludlum 3, MDA values for both fast (f) and slow (s) circuit responses have been listed. Also, typical efficiencies are listed for a Ludlum 3 with NaI probe.

Ludlum 2224 w/Model 43-89 125 cm² Rectangular Pancake Probe

Nuclide	Efficiency @ 1 cm	MDA
C-14	0.051	4,395 dpm (x1 scale)
P-32	0.421	532 dpm (x1 scale)
Cl-36	0.308	728 dpm (x1 scale)



Ludlum 3 w/Model 44-9 cm² Circular Pancake Probe

Nuclide	Efficiency @ 1 cm	MDA
C-14	0.049	3,711 dpm (fast)
		1,352 dpm (slow)
P-32	0.381	477 dpm (fast)
		174 dpm (slow)
Cl-36	0.115	1,582 dpm (fast)
		576 dpm (slow)
Sr-90	0.223	816 dpm (fast)
		297 dpm (slow)

Ludlum 3 w/Model 44-21 Low Energy Scintillation Cylindrical Probe, Circular End-Window

Nuclide	Efficiency @ 1 cm
C-14	0.053
P-32	0.270
I-125	0.191

More detailed information and pricing on Ludlum survey meters is available at:

Ludlum Inc.
501 Oak Street
Sweetwater, TX 79556
1-800-622-0828
www.ludlums.com

Rad Monitor Model GM2 w/1.75 in^2 Cylindrical Probe, Circular End-Window

Nuclide	Efficiency @ 1 cm	MDA
C-14	0.050	3,194 dpm
P-32	0.386	414 dpm
Cl-36	0.128	1,248 dpm
Sr-90	0.243	657 dpm

More detailed information and pricing on the RAD-MONITOR is available at:

Research Products International Corp.
410 N Business Center Drive
Mt. Prospect, IL 60056
1-800-323-9814 or 847-635-7330
www.rpicorp.com

If you need more information on survey meters and/or other manufacturers, contact the RSO at 716-1202.