

UNIVERSITY OF RICHMOND

Radiation Safety Manual

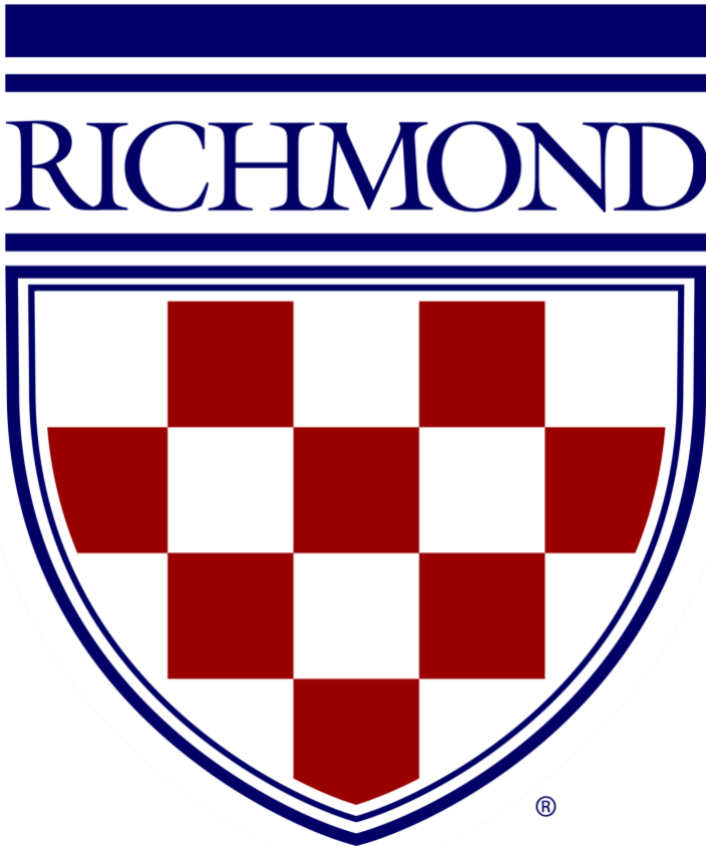


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A. Purpose

This safety manual has been developed to provide students, staff, and faculty at the University of Richmond with the information necessary to protect them and the surrounding community from possible hazards associated with the use of radioactive materials and/or radiation producing devices. It also provides procedures for ensuring that radiation doses are kept as low as reasonably achievable (ALARA).

B. Responsibility

There are four levels of group and individual responsibility in the total radiation safety program.

1. Radiation Safety Committee (RSC)

This committee functions under the Vice President of Business and Finance and is composed of various members of the University community. The committee is charged with ensuring that the ALARA philosophy is applied in all areas of radiation use. The Vice President for Business and Finance has the executive responsibility for all licenses and certificates of registration held by the University.

2. Radiation Safety Officer (RSO)

The Radiation Safety Officer advises and assists the Radiation Safety Committee to ensure that all radiation safety regulations set forth by the Nuclear Regulatory Commission, the Commonwealth of Virginia, and the University of Richmond are faithfully observed. The responsibilities include but are not limited to:

- a. Maintaining all pertinent records including personnel exposures, radioactive material disposals, surveys, leak tests and radioactive material transfers.
- b. Conducting periodic surveys of all laboratories and other areas where radioactive materials are used or stored. Each lab should be visited at least four times annually.
- c. Conducting special area surveys when appropriate.
- d. Conducting periodic surveys on all radiation producing devices on campus.
- e. Administering a monitoring badge system service.

- f. Disposing of radioactive waste in accordance with Federal and State regulations and sound radiation safety practices.
- g. Maintaining a liaison with the NRC, Commonwealth of Virginia, and other regulators concerning all licensing matters.
- h. Assisting Responsible Investigators in technical and administrative radiation safety problems.
- i. Monitoring and making recommendations regarding sources of non-ionizing radiation such as lasers and ultraviolet light sources.
- j. Ordering the immediate shut-down of an operation that is considered a major safety hazard because of violations of safety regulations. Such actions will be reported to the RSC chairman.

3. **Responsible Investigator**

This individual is responsible for the safe handling of all radiation sources under his/her authorization. This includes:

- a. Adequate planning. Before performing an experiment, the Responsible Investigator should determine the types and amounts of radiation or radioactive material to be used. The procedure involved should be rehearsed without radiation to avoid unseen problems or unexpected circumstances. In instances where there is a significant radiation hazard, the Radiation Safety Officer (RSO) must be consulted before proceeding with the procedure.
- b. Instructing employees and students under their authorization in appropriate radiation safety practices. Consult with RSO before allowing individuals under the age of 18 to work with radioactive material or radiation sources.
- c. Ensuring that all users complete the orientation training before working with radiation. (See section J: Personnel Training Program)
- d. Furnishing RSO with information concerning personnel changes and changes in radioisotope work areas.
- e. Complying with the regulations governing the use of radioactive materials and radiation producing devices, as established by the NRC, the Commonwealth of Virginia, and the RSC.
- f. Maintaining records of receipt, use, monitoring and disposal of radioactive materials.

- g. Complying with the proper procedure for termination of any authorization through the RSO. Should an investigator separate from the University, it is her/her responsibility to make certain that all radioactive materials are disposed of properly or transferred to another authorized individual. A termination survey of all work areas will be performed by the RSO.

4. **Individual User**

Each person who uses radiation is responsible for:

- a. Completing the orientation training before beginning work with radiation.
- b. Keeping his/her radiation exposure as low as reasonably achievable.
- c. Wearing appropriate personnel monitoring devices when deemed necessary by the RSO.
- d. Wearing lab coat and gloves when handling radioactive material other than sealed stock vials or sealed sources.
- e. Ensuring that required records are maintained.
- f. Performing swipe surveys of areas where radioactive materials are used. Geiger counter surveys are also recommended but cannot be substituted for swipe surveys.
- g. Labeling all radioisotope work areas, equipment, and radioactive waste.
- h. Reporting all incidents of accidental contamination to the RSO immediately.

C. **Procurement of Radioactive Materials**

1. **Orders:** All radionuclides used at the University of Richmond must be ordered through the Department Lab Manager. The Lab Manager must receive approval from the RSO for each order. This ensures that both the institution and the Responsible Investigator are authorized to use the material requested, and that license limits are not exceeded for the specific materials.
2. **Transfer of Radionuclides:** Transfer of radionuclides from one Responsible Investigator to another (within the University) is subject to approval by the RSO. A transfer must be completed so that inventories

may be adjusted and authorizations can be verified. The transfer form is available from the RSO.

D. Policies and Procedures for Radionuclide Areas

The following policies and procedures shall apply to all areas where radionuclides are used or stored:

1. Proper posting and labeling of laboratory areas and equipment

All laboratories using radioactive materials shall display the appropriate sign outside the laboratory entrance. Safety and Risk Management will determine the type of sign necessary and ensure posting.

Label radioactive waste containers, radioisotopic storage areas radioisotopic work areas and any equipment routinely used for radioisotope work with “Caution Radioactive Materials” labels.

Spill procedures are required to be posted in all laboratories using radioisotopes.

2. Shielding of sources

Radioactive sources or stock solutions in the laboratory must be shielded so that the radiation levels in any surrounding area will not expose individuals in that area to more than 2 millirem in any one hour.

3. Protection of work surfaces

All radioisotope work areas (bench tops, hood floors, etc.) as well as storage areas should be covered at all times with stainless steel or plastic trays, uncracked glass plates, or other impervious materials with a protective liner. In most cases a plastic-backed absorbent paper will be satisfactory. However, if such paper is used, it should be replaced after each experiment to prevent a build-up of radioactive contamination and placed in a radioactive solid waste container.

4. Laboratory records

All Responsible Investigators using radioactive materials are required to maintain a record of receipt and use of radioisotopes, copies of waste disposal records, results of routine lab monitoring, copies of radionuclide inventory reports, and any correspondence with the Environmental Health and Safety Office.

All records pertaining to the receipt, use, monitoring and disposal of radioisotopes must be kept for three (3) years. After that time, they may be discarded.

5. Routine monitoring of work areas

Routine monitoring for radioactive contamination is a necessary part of the laboratory program and is required in areas where radioactive materials are used and stored. A diagram of these areas must be kept in the monitoring section of the radioisotope log book. Monitoring is accomplished by using swipe tests, also called wipe or smear tests. For gamma or high energy beta emitters (^{125}I , ^{32}P , ^{22}Na , ^{51}Cr), monitoring with a Geiger counter is recommended but cannot be substituted for swipe monitoring.

The purpose of swipe monitoring is to determine the presence of removable radioactive contamination on a surface. The test is done by wiping, with slight pressure, a piece of filter paper, parafilm, or commercially prepared swipe paper over the surface area of counter tops, laboratory furniture, equipment, handles, floors, etc. Each swipe sample should cover an area of about 100 square centimeters.

-Count the swipe samples in the appropriate analyzer (biodegradable scintillation fluid in liquid scintillation or gamma counter) for one minute using a wide open window. (A conservative 10% counting efficiency is assumed for research labs.)

-Count a background swipe with each group of swipes assayed for contamination.

-Investigate and decontaminate areas with swipe results greater than 200 counts per minute above background. Then re-swipe the area, and enter all results in the monitoring section of the radioisotope log book. Swipe results showing contamination as well as the swipe results after decontamination must be kept in the record book with appropriate notations such as date, name and isotope.

-Swipe surveys are required each calendar week, or after each use of radioactive material, if the frequency of use is less than weekly. Records must include both positive and negative results, the count time, and the date of the survey. Label the printout from the liquid scintillation or gamma counter with the corresponding location numbers from the room diagram and file in the monitoring section of the radioisotope log book.

After use of gamma or high energy beta emitters (^{125}I , ^{32}P , ^{22}Na , ^{51}Cr), the user should perform an immediate survey (by using a Geiger counter) of personnel and use areas for gross contamination.

6. **Radioactive contamination**

An action level for radioactive contamination is the level that required investigation, decontamination, and re-swiping. The action level for areas approved for use and storage of radioactive materials is 2,000 dpm which equates to 200 cpm when a 10% counting efficiency is assumed.

To prevent personnel contamination, laboratories that are approved for radioactive material should be keep unprotected, unlabeled surfaces such as desks and computer work stations free of contamination. Exceptions include specified protected work areas and equipment which are frequently used for radioisotope work and which are clearly labeled with the standard radiation caution signs or stickers.

7. **Decontamination of areas**

- a. Begin decontamination immediately. Contain all spills with absorbent material or paper towels. Decontamination materials must be handled as radioactive waste.
- b. Determine the extent and hazard of the contamination.
- c. Clean the contaminated area with soap solution. Perform a swipe survey for removable contamination.
- d. In general, the individual responsible for the contamination will be expected to do the cleanup.
- e. After decontamination, the area or equipment should be considered contaminated until proven otherwise by a swipe survey.

8. **Decontamination of personnel**

- a. Notify supervisor or Responsible Investigator immediately.
- b. Remove contaminated clothing and flush contaminated skin with lukewarm water and then wash with mild soap. If contamination remains, induce perspiration by covering the area with plastic. Then wash the affected area again to remove any contamination that was released by the perspiration. If the contamination persists, call the Safety and Risk Management Office before attempting further decontamination.

9. **Quarterly laboratory surveys**

The RSO is required to conduct inspections of all laboratories using radioactive materials. The inspection will include a review of the

laboratory records, personnel monitoring requirements, safety equipment and procedures, waste disposal techniques and an independent evaluation of radiation and contamination levels.

10. Calibration of Geiger Counters

Investigators are required to purchase a Geiger counter to monitor personnel and surface contamination if research is conducted with radionuclides other than ^3H . All Geiger counters must be registered with Safety and Risk Management to ensure timely calibration. The RSO will ensure that all Geiger counters are calibrated annually.

E. Laboratory Rules for the Safe Use of Radioactive Materials in Research Areas

1. Eating, drinking, smoking, and the application of cosmetics is not permitted in radioisotope laboratories.
2. Train employees and make workers aware of existing and potential hazards, such as radionuclide packages, waste containers, and storage vaults, by marking them with correct warning signs. For posting requirements and warning signs, contact the Safety and Risk Management Office.
3. Perform swipe tests on floors and surfaces each calendar week or after each use of radioactive material if use is less frequent than weekly.
4. Make arrangements with Environmental Health and Safety for leak testing of beta and gamma sealed sources subject to State control twice a year, and of alpha sources four times a year.
5. Maintain a log book containing such information as radionuclide receipt, use, disposal, swipe tests and area monitoring results. Keep these records current, and include up-to-date radionuclide authorizations. The log book is subject to inspection by Safety and Risk Management, and State personnel.
6. Make shielding and monitoring equipment available where applicable.
7. Order and dispose of all radioactive material according to University policy in this manual.
8. Minimize opportunities for personnel contamination. Food and drink and associated utensils shall not be stored in areas where radioactive materials are used. Solutions shall never be pipetted by mouth.
9. Lock areas where radioactive materials are kept when the area is

unoccupied.

10. Store radioactive sources in a shielded enclosure when not in use. Ensure that radiation levels at accessible places are less than 2mR/hr.
11. Hands should be washed before leaving the lab. Hands, clothes, and shoes should be monitored on a routine basis.
12. Radionuclides which can exist in a volatile state must be handled in a glove box or exhaust hood fitted with an appropriate filter unless exempted by the RSO.
13. Perform procedures which could conceivably lead to spillage of radioactive liquid over special absorbent paper, preferably placed in the bottom of a tray.
14. Report any major radionuclide spillage immediately to the Environmental Health and Safety Office.
15. Use protective clothing: Gloves and lab coats are required when handling radioactive material. Protective clothing shall not be taken out of the local areas in which they are used. Gloves must be discarded prior to leaving the area and placed in the appropriate container. Lab coats are not to be worn outside the area. Contaminated clothing, i.e., lab coats, shall be placed in appropriate containers and will be disposed of as radioactive waste or held in the radioactive decay room for decay and then disposed of per established procedures.
16. Tweezers, tongs, or other suitable devices should be used as needed to handle sources with significant surface dose rates. Maintaining a distance of even a few inches with tweezers or tongs can cut down the exposure rate by orders of magnitude relative to handling small sources directly with the fingers.

F. Radioactive Waste

1. Procedures

- a. Carefully plan work with radioactive materials to minimize the volume of waste generated. Use care to separate radioactive from non-radioactive waste as it is generated. Do not place non-radioactive waste in radioactive waste containers. Segregate waste into appropriate categories; it is important that different types of waste not be mixed. Remove or deface all radioactive waste labels from packages before disposal.
- b. Authorized Users are responsible for ensuring that their waste is

packages, labeled and recorded properly. Waste cannot be accepted by the RSO unless it has been correctly identified.

- c. Radioactive waste will be disposed of by one of the following methods: release to the sanitary sewer in conformance with local, state and NRC regulations, decay in storage, or transfer to a licensed disposal site. The RSO will decide the most appropriate manner of disposal.
- d. Store radioactive waste only in restricted areas where it can be secured against unauthorized removal. Do not allow radioactive waste to accumulate in a lab. When a waste container is full, notify the RSO for removal to the central storage area.
- e. Place containers that may break in a secondary container that is large enough to hold the contents. Liquid containers must have a screw type lid.
- f. Separate radioactive waste into dry solids, aqueous, and non-aqueous waste. Dry solid waste is primarily composed of paper, plastic, syringes, and glass that becomes contaminated during work with isotopes. No free liquid, other than trace amounts, is allowed in this type of waste. Liquid scintillation fluids constitute the major portion of non-aqueous waste.
- g. Collect dry solids in plastic-lined 5-gallon/20-gallon containers. Waste containers must be approved by the RSO. Place syringes in smaller containers that are puncture resistant and tape the lid shut. Do not overfill the bag. Leave sufficient room at the top so the bag can be twisted and sealed with strong tape.
- h. Separate aqueous from non-aqueous waste. Collect bulk liquids in 1-gallon or 5-gallon plastic or glass containers. Do not use plastic milk jugs. Segregate aqueous liquids containing ^3H or ^{14}C from all other aqueous liquids to simplify sink disposal by the RSO.
- i. Collect all original solutions and first rinses as waste. Other rinses or equipment decontamination water can be released into the sanitary system if certain criteria are met. The liquid must be readily soluble or dispersible in water. The maximum release cannot exceed $1\ \mu\text{Ci}$ per day. Any release must be flushed with copious amounts of water.
- j. Pack scintillation vials in a separate labeled waste can lined with a thick plastic bag. Place a layer of absorbent material in the bottom. Collect the vials in an upright position. Segregate vials with specific activities less than $0.05\ \mu\text{Ci/ml}$. In addition, separate vials containing ^3H and ^{14}C with less than $0.05\ \mu\text{Ci/ml}$ from other vials.

- k. Segregate radioactive waste into the following categories based on half-life:
 - i. Very short (less than 15 days) ex: ^{32}P
 - ii. Short (15-65 days) ex: ^{33}P , ^{125}I
 - iii. Intermediate (65-90 days) ex: ^{35}S
 - iv. Long (gtr than 90 days) ex: ^{14}C , ^3H
- l. Waste with half-lives less than 90 days will be stored at the university in the radioactive waste storage room. After 10 half-lives the waste will be surveyed and discarded in the regular trash if found to be at background levels. Waste with half-lives greater than 90 days will be shipped off site for disposal by an undetermined licensed firm.
- m. Animal Carcasses
 - i. Animal carcasses containing isotopes with half-lives less than 120 days will be held for decay a minimum of ten half-lives, monitored and disposed as regular trash. Records of monitoring will be maintained as required in 10 CFR 20.2108. All other animal carcasses will either be packaged and transferred to a commercial disposal firm or disposed per CFR 20.2005 (a)(2).

G. Personnel Monitoring

1. TLD Badge:

- a. The TLD badge is the personnel monitoring device used at U of R. The Environmental Health and Safety Office will determine individuals who require monitoring when they apply for authorization or are listed as additional users.
- b. TLD badges will be used for personnel monitoring; they are exchanged on a quarterly basis, and the company providing the service is accredited by the National Voluntary Accreditation Program (NVLAP) of the National Bureau of Standards.

H. Emergency Procedures

1. **Minor Spills of Liquids and Solids:** Less than 1mCi and less than 5 milliliters of liquid confined to a small area.
 - a. Notify persons in that area that a spill has occurred.
 - b. Prevent the spread of contamination by covering the spill with absorbent paper.
 - c. Clean up the spill wearing disposable gloves and using absorbent paper. Carefully fold the absorbent paper with the clean side out and place in a plastic bag for transfer to a radioactive waste container. Also put contaminated gloves and any other contaminated disposable material in the bag.
 - d. Survey the area with a Geiger counter. Check the area around the spill. Also check your hands, clothing, and shoes for contamination.
 - e. Decontaminate the area with a soap solution. Perform a swipe survey of areas where contamination is possible. Continue decontamination efforts until swipe surveys show less than 200 cpm removable contamination. Keep record of swipe results.
 - f. Report the incident to the Radiation Safety Officer at 289-8721
2. **Major Spills of Liquids and Solids:** Greater than 1 mCi and greater than 5 millimeters of liquid, or a smaller volume of liquid spread over a large area.
 - a. Clear the area. Notify all persons not involved in the spill to vacate the room.
 - b. Prevent the spread of contamination by covering the spill with absorbent paper, but do not attempt to clean it up. To prevent the spread of contamination, limit the movement of all personnel who may becontaminated.
 - c. Shield the source if possible. This should only be done if it can be done without further contamination or significant increase in radiation exposure.
 - d. Close the room and lock or otherwise secure the area to prevent entry.
 - e. Notify the RSO immediatelyat 289-8721 or 289-8824.

- f. Decontaminate personnel by removing contaminated clothing and flushing contaminated skin with lukewarm water and then washing with mild soap. If contamination remains, induce perspiration by covering the area with plastic. Then wash the affected area again to remove any contamination that was released by the perspiration.

I. The ALARA Concept

The **ALARA** concept means keeping radiation exposure **As Low As Reasonably Achievable**. The University, the Radiation Safety Committee and the Office of Safety and Risk Management are committed to implementing the **ALARA** concept.

1. Work should be planned so that unnecessary exposure of the individual worker and the worker population to radiation is minimized.
2. Radiation workers are encouraged to participate in the development of the **ALARA** procedures that they will be required to follow.
3. Suggestions for improving health physics practices are encouraged from individual radiation workers. These suggestions should be given to the RSO.
4. The Responsible Investigator will ensure that supervised individuals who are subject to occupation radiation exposure are trained and educated in good health physics practices for their specific work procedures and in maintaining exposures **ALARA**.

J. Personnel Training Program

Personnel will be instructed:

1. Before assuming duties with, or in the vicinity of radioactive materials.
2. During periodic refresher training.
3. Whenever there is a significant change in duties, regulations, or the terms of the license.

Instruction will include the following:

1. Viewing Radiation Safety Video.
2. Applicable regulations and license conditions.
3. Areas where radioactive materials are used or stored.

4. Potential hazards associated with radioactive material in each area where the employees will work.
5. Appropriate radiation safety procedures.
6. Licensee's in-housework rules.
7. Each individual's obligation to report unsafe conditions to the Radiation Safety Officer.
8. Appropriate response to emergencies or unsafe conditions.
9. Worker's right to be informed of occupational radiation exposure and bioassay results.
10. Locations where the licensee has posted or made available notices, copies of pertinent regulations, and copies of pertinent licenses and license conditions.

Records that Document Training:

Records of initial and refresher training will be maintained and will include:

1. The name of the individual who conducted the training
2. The names of the individuals who received the training
3. The dates and duration of the training session; and
4. A list of topics covered.

K. Procedures for Receiving and Safely Opening Packages Containing Radioactive Material

Note: All orders for radioactive materials shall be placed through the Lab Manager. The Lab Manager must received approval from the RSO for each order. Delivery shall be requested during normal working hours.

1. Receipt of Packages

The following procedures will be followed by all those who come in contact with a person delivering a package containing radioactive materials.

- a. Packages will be visually inspected by the Bio/Chem stockroom manager to confirm that it is intact. If the package is wet or

crushed the Radiation Safety Officer (RSO) will be notified immediately. The package will then be monitored with the appropriate equipment to determine if contamination is present.

- b. The Virginia Department of Health and the final delivery carrier shall be notified if removable contamination exceeds the limits of 10 CFR 71.87 (I), or if external radiation limits exceed the limits of 10 CFR 71.47.

2. External Monitoring of Packages

- a. Visually inspect the package for any signs of damage (e.g., wet or crushed) and monitor all packages if there is evidence of degradation.
- b. Monitor the external surfaces of a labeled* package for radioactive contamination unless the package contains only radioactive material in the form of a gas or in special form as defined in 10 CFR 71.4.
- c. Monitor the external surface of a labeled* package for radiation levels.
- d. Monitoring shall be performed as soon as practicable after receipt of the package during normal working hours.

3. Opening Each Package

- a. Put on gloves to prevent hand contamination.
- b. If applicable, from Step 2 of this procedure, measure the exposure rate from the package and/or swipe the external surface of the package. If the exposure rate exceeds 10 mR/hr at 3 feet, or 200 mR/hr at the surface, immediately notify the RSO.
- c. Open the package with the following precautionary steps:
 1. Remove the packing slip.
 2. Open the outer package following the supplier's instructions, if provided.
 3. Open the inner package and verify that the contents agree with the packing slip.

* Labeled with a Radioactive White I, Yellow II, or Yellow III label as specified in U.S. Department of Transportation regulations 49 CFR 172.436-440.

4. Check the integrity of the final source container. Look for broken seals or vials, loss of liquid, condensation, or discoloration of the packing material.
- d. If there is any reason to suspect contamination, wipe the external surface of the final source container and remove the wipe sample to a low-background area. Assay the wipe to determine if there is any removable radioactivity. Take precautions against potential spread of contamination.
- e. Check the user request to ensure that the material received is the material that was ordered.
- f. Record the record of receipt and other pertinent information in the Radioisotope Log Book and on the chemical inventory card.
- g. Notify the Responsible Investigator that the material has been received. The Responsible Investigator must sign the log sheet when taking possession of the material.
- h. The packing material and empty packages shall be monitored for contamination before discarding.
 1. If contaminated, treat this material as radioactive waste.
 2. If not contaminated, remove or obliterate the radiation labels before discarding in regular house trash.

L. Safety Instructions for Individuals handling $>1\text{mCi}$ of ^{32}P

^{32}P radiation can be absorbed from a source external to the body, in contact with the body. ^{32}P emits beta particles which generate secondary radiation when striking other materials.

One of the greatest hazards associated with beta emitters of this energy level exists in handling uncovered vessels containing ^{32}P . Air does not significantly attenuate the radiation. Therefore, shielding materials should be placed between the source and personnel to absorb most of the radiation. The best shield for a ^{32}P source is a material like Lucite (1/2 inch thick) or other plastic, which will absorb the beta particles while generating little secondary (Bremsstrahlung) radiation.

Guidelines for Safe Handling of ^{32}P

1. Store ^{32}P and handle millicurie quantities behind 1/2 inch thick Lucite shielding.

2. Individual performing procedures that involve 1 millicurie or most must wear finger extremity monitors.
3. Plan and practice operations to eliminate unnecessary exposure. Request that the RSO be present during new procedures. All new procedures must be reviewed and approved by the RSO.
4. Individuals performing procedures that involve 10 millicuries or more must wear appropriate eye protection.
5. A mandatory radiation survey and wipe test for radioactive contamination is required after each experimental run involving ^{32}P .
6. Protective clothing (gloves, lab coat) must be worn.
7. Carefully use transfer pipets, spill trays and absorbent coverings to confine contamination. Never pipet by mouth.
8. Promptly clean up spilled liquids to prevent spread of contamination.
9. Place contaminated paper and gloves in a radioactive waste container for proper disposal.

Appendix A

Permissible Levels of Radioactive Material Disposal via Sanitary Sewer University of Richmond – Gottwald Science Center

I. Assumptions

Total sewer discharge/year (campus wide) = 104,903 ccf

1 ccf = 100ft³,

- Total sewer discharge/year (campus wide) = 10,490,300 ft³

Gottwald sewer discharge ≈ 4% total discharge

- Gottwald discharge/year = 209,806 ft³/year or 17,483 ft³/month

This is equal to a discharge rate of 4.9×10^8 ml/month.

Example: If the University of Richmond was approved by the State License for 13 different isotopes, and for the purposes of these calculations, each isotope discharge would count 1/13 (7.7%) toward the total unity discharge as specified in 10 CFR 20, Appendix B.

II. Average Monthly Unity Release Calculation

To determine the permissible levels of disposal via the sanitary sewer, the monthly average concentration (μCi/mo) of each isotope was examined. Each concentration was multiplied by 7.7% to obtain the maximum permissible amount allowed for disposal, assuming that all isotopes would be disposed in equal amounts in any given month.

Monthly Average Concentrations

Isotope	License Limit (mCi)	Monthly Average Concentration (10 CFR 20)	Monthly Corrected Average Concentration (7.7% of Column 3)
H-3	25	1×10^{-2}	7.7×10^{-4}
C-14	10	3×10^{-4}	2.3×10^{-5}
Na-24	5	5×10^{-4}	3.9×10^{-5}
P-32	25	9×10^{-5}	6.9×10^{-6}
P-33	10	8×10^{-4}	6.2×10^{-5}
S-35	25	1×10^{-3}	7.7×10^{-5}
Cl-36	3	2×10^{-4}	1.5×10^{-5}
K-42	5	6×10^{-4}	4.6×10^{-5}
Ca-45	3	2×10^{-4}	1.5×10^{-5}
Cr-51	20	5×10^{-3}	3.9×10^{-4}
Fe-59	10	1×10^4	7.7×10^{-6}
Rb-86	10	7×10^{-5}	5.4×10^{-6}

I-125	5	2×10^{-5}	1.5×10^{-6}
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III. To calculate the total amount of radioactivity that may be disposed per month via the sanitary sewer, the following formula was used:

$$\#\mu\text{Ci/month} = \text{Discharge Rate (ml/month)} \times \text{Monthly Average Concentration (Column 4)}$$

The following values were calculated for each isotope:

Isotope	Monthly Average Concentration	Total Amount Allowed for Monthly Disposal (μCi)
H-3	7.7×10^{-4}	377,300
C-14	2.3×10^{-5}	11,270
Na-24	3.9×10^{-5}	19,110
P-32	6.9×10^{-6}	3,381
P-33	6.2×10^{-5}	30,380
S-35	7.7×10^{-5}	37,730
Cl-36	1.5×10^{-5}	7,350
K-42	4.6×10^{-5}	22,540
Ca-45	1.5×10^{-5}	7,350
Cr-51	3.9×10^{-4}	191,100
Fe-59	7.7×10^{-6}	3,773
Rb-86	5.4×10^{-6}	2,646
I-125	1.5×10^{-6}	735
TOTAL:	<1 (unity)	

University of Richmond Annual Program Review

DATE	Changes Made to Program	INITIALS
3/21/23	Uploaded updated program to website	SM
2/19/24	Uploaded updated program to website	AM