X-rays are a form of electromagnetic radiation. Other types of electromagnetic radiation include radio waves, microwaves, infrared, visible light, ultraviolet light, and gamma radiation. X-rays are similar to gamma rays in that they both ionize atoms, but differ in their point of origin. Gamma rays originate from within the nucleus of an atom, whereas x-rays originate from the electron shell and from free electrons decelerating in the vicinity of atoms.

Radiation generating equipment (RGE) produce x-rays by accelerating electrons through an electrical voltage potential and stopping them in a target. Many devices that use a high voltage and a source of electrons produce x-rays as an unwanted byproduct of the device’s operation (e.g., electron microscope). Most RGE emit electrons from a cathode, accelerate the electrons with a voltage, and allow the electrons to strike an anode, which emits x-rays. The voltage of the system will determine how penetrating the x-rays will be. The higher the voltage of the generator, the more energetic and the more penetrating the produced x-ray. When x-rays pass through material some will be transmitted, some will be absorbed, and some will scatter. The proportion of transmitted versus absorbed, versus scattered depends on the x-ray energy, the type of material and the material thickness.

X-rays can penetrate into the human body and ionize atoms within the body. To protect personnel from these penetrating rays, dense material (e.g., lead, steel) is used as shielding. Certain analytical systems (e.g., x-ray diffraction) use voltages that produce low energy (e.g., 1–50 keV) or soft x-rays. Soft x-rays with energies from 1 to 20 keV are absorbed in the first few millimeters of the skin, although for extremities, some of this radiation may also be absorbed in the bone. Soft x-rays may produce skin reddening at exposures of approximately 300 rem (300,000 mrem), while skin burns can result from exposures above 500 rem (500,000 mrem). Because some types of analytical x-ray systems can produce exposure rates between 1 and 1000 rem/hr, even short exposure to the direct beam can produce significant damage. For that reason, the primary radiation beam must always be contained in a shield.

The basic radiation protection principles of time, distance, and shielding apply equally to x-ray and radioactive materials. Implementation of these principles for x-rays includes:

- **TIME:** When you need to use an x-ray system, work quickly and efficiently.
- **DISTANCE:** When dealing with a narrow beam or a point source, the dose from an x-ray source is inversely proportional to the square of the distance. This is referred to as the “inverse square law.” When you double the distance from a point source of x-rays, the dose is reduced to one-fourth of the original value.
- **SHIELDING:** Shielding is a barrier between the x-rays and personnel. It is one of the most effective mechanisms for protecting workers from unnecessary x-ray exposure. Always operate x-ray systems with all shielding in place.

Before operating any RGE, the operator must ensure they are familiar with the RGE’s operating characteristics, as well as the purpose and function of the protective devices. Any operator who has questions or doubts regarding the operation of an RGE should immediately seek guidance from their supervisor or other appropriate individual. Operators shall report prompt-
Precautions and guidelines when operating an RGE:

- Get proper training/instruction from the Contact Person before operating any RGE.
- Closely following RGE operating procedures.
- Ensure to wear issued dosimeters when operating an RGE.
- Reduce the time in the designated restricted area (area where the dose rate may exceed 2 millirem in any one hour).
- Stay as far away as possible from the radiation beam.
- Never override interlocks or other safety features.
- Do not work in an open, unshielded beam. However, if it is necessary to work near the unshielded radiation beam (e.g., for system alignment):
  - Reduce beam current (mA) and the beam energy (kV) to the lowest settings possible to reduce exposure rates.
  - Keep hands and body at a safe distance from the beam.
  - Use appropriate alignment tools.
  - Carefully follow the manufacturer’s procedures for the process.
  - Stay alert and always be aware you are in a potentially hazardous situation.
- Never assume an RGE was left in a safe working condition by the previous user. Always perform a preoperational check of the RGE prior to use.
- If working with an open beam, the unit may not be left unattended and the operator must always be immediately present.
- Secure all unused ports from casual opening.

The principle hazard with most analytical RGE is the possibility of exposure of the hands to the direct beam. The general precautions and operational guidelines are considered to be the minimum requirements to be followed to help ensure that radiation exposures will be As Low As Reasonably Achievable (ALARA).

**RAM SECURITY**

Ensuring radioactive material (RAM) security continues to be a significant concern. Always be aware of who is in your laboratory and confront any unfamiliar individuals. Keep RAM locked up or under direct observation at all times to prevent an unauthorized person from removing the RAM or gaining access to the RAM. The last person leaving a RAM-use laboratory should ensure the door to the laboratory is either locked or all of the RAM inside the room, including waste, is locked up.

**CAPTCHA**

In July 2011, the requests feature on the Radiation Safety website (www.uc.edu/radsafety) began experiencing significant problems with spam. In an effort to reduce the spam, a CAPTCHA was added to each of the requests. A CAPTCHA (completely automated public Turing test to tell computers and humans apart) requires a human being to recognize mildly distorted letters displayed and enter the sequence of letters correctly in a response. When requesting a waste pickup or special survey, the displayed letters must be entered correctly prior to submission. If the letters are not entered correctly, the submission will not be processed and the user will be redirected back to the original request page to try again. This corrective action has eliminated the spam. If you have questions or problems with the CAPTCHA, please contact the Radiation Safety Office (RSOf) at 558-4110.

**WARM WEATHER PPE**

Personal Protective Equipment (PPE) is worn to protect an individual from contamination. No skin should be exposed where the possibility exists for contamination. Shorts and skirts with bare legs, and open-toed shoes (e.g., sandals) do not provide adequate protection should an accident involving radioactive material (RAM) occur. Authorized Users (AU) need to remind their staff and pay close attention to ensure laboratory workers wear proper protection in warm weather.
The Radiation Safety Office (RSO) occasionally receives Radioisotope Use Record cards requiring follow-up due to apparent errors or missing information. The intent of this article is to provide some guidance and minimize the need for follow-up. Laboratory staff members may call the RSO at 558-4110 to obtain assistance and/or more training on the proper completion of Radioisotope Use Record cards.

The RSO completes the items marked with the symbol ® on the sample card below. All others are completed by laboratory personnel. Items beginning with "*" in the descriptions below are optional.

**RADIOISOTOPE USE RECORD CARD COMPLETION**

The upward part of the card includes:
- **Dept.** – Authorized User’s (AU) department.
- **AU Name** – AU who ordered the radioactive material (RAM).
- **Date Rec’d** - Date RAM received at RSO.
- **Activity Rec’d (mCi)** - Activity in millicuries of RAM received.
- **Date on Vial** - The calibration date for the listed activity.
- **Radionuclide** – Radionuclide.
- **Compound** – The radiolabeled compound.
- **Original Volume (ml)** – The volume in milliliters.
- **PO#** - The purchase order number.
- **Multi-cards** – Used if more than one vial received in a shipment. Is not used if only one vial.

**T¹/₂ Category** – Indicates the half-life category for RAM waste disposal.
- L1 (≤ 15 days)
- L2 (> 15 days, ≤ 65 days)
- L3 (> 65 days, ≤ 120 days)
- L4 (> 120 days)

**Upper Part of Card**

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<th>VOLUME (ml)</th>
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<th>% REUSE VOLUME</th>
<th>HOW USED</th>
<th>% KEPT FOR REUSE</th>
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<th>NS</th>
<th>SL</th>
<th>HL</th>
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**Table**

- **DATE** – Date RAM is removed for use.
- **ACTIVITY** – The estimated activity in millicuries removed from the stock vial.
- **VOLUME (ml)** – The volume in milliliters removed from the vial.
- **% ORI. VOL. or REUSE DATE** – This column has dual uses.
  - Percent of volume removed from the stock vial. (Note: These percents should add up to 100% if all RAM is gone from the stock vial.)
  - Date(s) of use from a reuse percent.
- **% REUSE VOLUME** – The percent of any volume from an original volume or a reuse volume that is not disposed.
- **HOW USED** – Short description of experimental protocol. (May be abbreviations or codes used by laboratory personnel.)
- **% KEPT FOR REUSE** – The percent of any volume from an original volume or a reuse volume that is not disposed.
- **CS, NS, SL, HL, SV, PT, IW** – These columns are used to describe the disposal path for the RAM used on the recorded date. The abbreviations are defined at the bottom of the card. The percents are good guesses. For a line, percents in these columns and % kept for reuse must add up to exactly 100%.
SPILL/CONTAMINATION REPORTING

The Authorized User has the ultimate responsibility for radioactive material (RAM) use and must be informed of any radioactive material spill or contamination, even if it is not required to be reported to the Radiation Safety Office (RSOf). Section 12.2.2.1 of the University of Cincinnati Radiation Protection Procedures Manual—Authorized User Manual (AU Manual) lists examples of incidents involving contamination that require immediate verbal notification to the RSOf. This article discusses three basic scenarios that may require an immediate report to the RSOf. The scenarios are: 1) RAM is observed being spilled, 2) Contamination is detected during a survey, and 3) Contamination is detected on a lab coat.

OBSERVED SPILL
Always remember to SWIM for a spill. Stop the spill, Warn others, Isolate the area, and Minimize personnel exposures. Under the Radiation Control and Safety Program (RCSP) there is an activity threshold for spill reporting. If greater than 100 uCi is being used at the time of the spill, the spill must be immediately reported to the RSOf. If ≤100 uCi is being used and the radioactive material is completely contained within the marked RAM work area, it is not necessary to immediately report the spill. For the second scenario, promptly clean up the spill, perform a survey of yourself, and perform a detailed post-decontamination survey of the spill area, the immediate surrounding areas, and the floor in the immediate area. If contamination is detected anywhere outside the labeled RAM work area, immediately call the RSOf.

CONTAMINATION DETECTED DURING A SURVEY
Reporting requirements are dependent on where and how much contamination is detected. RSOf notification is not required for contamination detected within a labeled RAM work area. If contamination is detected that is greater than 1000 cpm/100 cm² outside the labeled RAM work area, an immediate report to the RSOf is required. An immediate report to the RSOf is also required anytime contamination is detected on the floor.

CONTAMINATED LAB COATS
Lab coats are Personal Protective Equipment (PPE) that may become contaminated while carrying out their basic function of protecting the wearer from radioactive contamination. The RSOf is to be immediately informed about contamination on a lab coat if the contamination levels are above those allowed in a restricted area. Restricted area levels are listed in Table 1 of the AU Manual. For example, the RSOf must be immediately informed if P-32, P-33 or I-125 contamination greater than 2200 dpm/100 cm² is detected on a lab coat. The RSOf must also be notified if C-14, H-3 or S-35 contamination greater than 22,000 dpm/100 cm² is detected on a lab coat. If the contamination detected on the lab coat does not require reporting to the RSOf, the lab coat may be disposed as RAM waste by documenting the survey, completely a Radiation Incident Report Form (RS Form 7), and placing the lab coat into a combustible solid (CS) waste container. If the contaminate radionuclide has less than a 120 day half-life, laboratory personnel may request to have the lab coat held for decay and subsequent return.

The preceding scenarios cover the most common incidents that require mandatory reporting to the RSOf; however, the RSO recommends a report to the RSOf be made anytime there is concern about contamination. Upon receiving a report, an RSOf staff member will be dispatched to survey and assist. The RSOf may be reached during normal business hours at 558-4110 or by calling the on-call technician’s digital pager (249-6812) at any time.

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