جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Radiation Safety Manual

July 2024

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1. Introduction

The King Abdullah University of Science and Technology (KAUST) is a distinguished research institution while prioritizing health, safety, and environmental protection. Ionizing radiation is frequently used for teaching and research purposes at KAUST, such as X-ray analysis and biological sample labeling. Radiation Safety Program serves as framework and resources to ensure the safety of all KAUST researchers and employees. This program is designed to ensure safe use of radioactive substances and radiation equipment. The RSP aims to minimize radiation exposure by providing guidelines, procedures, and monitoring programs for the safe use of radioactive materials and radiation-producing equipment. Various individuals are responsible for implementing the RSP, which includes a radiation safety manual, procedures, guidelines, forms, dose monitoring, and audits.

The use of ionizing radiation in KAUST is under the license of Research and Education Practice granted by the Regulatory Authority (NRRC).

The Radiation Safety Officer (RSO) together with the Institutional Radiation Safety committee (IRSC), manages the RSP, outlining requirements for users of radioactive sources and providing guidance for their safe use.

National Competent Authority on Radiation Protection

The Nuclear and Radiological Regulatory Commission (NRRC) is an independent government organization established by royal order in April 2018 to replace King Abdullah City for Atomic and Renewable Energy as the competent authority. The NRRC is responsible for supervising and controlling all works related to the use of atomic energy and the resultant radioactive waste. It acts as the Competent Regulatory Authority for all aspects relating to regulations, rules, national limits, and licensing for the use of ionizing radiation in the Kingdom of Saudi Arabia (KSA).

The legal framework and the basic reference for any practice involving ionizing radiation in Saudi Arabia are explained by the following promulgates of the Saudi Competent Authority, the Nuclear and Radiological Regulatory Commission (NRRC):

Legislative Framework

- The Law on Nuclear and Radiological Control
- The Law on Civil Liability for Nuclear Damage
- The Status of the Nuclear and Radiological Regulatory Commission (NRRC)

Technical Regulations

- (NRRC-R-01) Radiation Safety
- (NRRC-R-02) Notification on and Authorization of Facilities and Activities with Radiation Sources
- (NRRC-R-03) Licensing and Regulatory Oversight of Nuclear Facilities
- (NRRC-R-04) Leadership and Management for Safety
- (NRRC-R-07) Safety Assessment of Nuclear Facilities
- (NRRC-R-12) Nuclear Material Accountancy and Control
- (NRRC-R-14) Nuclear Facilities Emergency Preparedness and Response
- (NRRC-R-16) Management of Radioactive Waste
- (NRRC-R-17) Security of Radioactive Materials

2. Scope

The Radiation Safety Program is a framework in support of the Health and Safety Policy. This program is applicable to the use of radioactive substances and radiation-producing equipment at all KAUST research spaces (Research Park activities are not governed under this program).
The program covers radiation sources from the approval of purchase stage through to final disposal, as well as the shipping of these materials and devices within and away from KAUST research spaces.
The Safety Training Program is applicable to anyone who works for, on behalf of, or is affiliated with KAUST and who is engaged in any research or project activities owned or co-owned by KAUST, including:

- Faculty
- Staff
- Postdoctoral fellows
- Students
- Visiting scientists

The objectives of the Radiation Safety Program (RSP) are to:

- Establish a framework in managing radiation safety for academic and research activities
- Ensure full compliance with applicable regulations; Saudi Competent Authority, the Nuclear and Radiological Regulatory Commission (NRRC) and accepted good practices
- Ensure that research activities involving the use of ionizing radiation sources adopts ALARA principle.
- Manage risks associated with ionizing radiation according to the program detailed below and various protocols specific to each device/laboratory.
- Establish periodic RSP's safety indicators reporting to Institutional Radiation Safety Committee (IRSC).

Adherence to the program and associated documents detailed in this manual will ensure that radioactive substances and/or radiation-producing equipment are handled safely. Failure to comply with these requirements may not only threaten the safety and health of faculty, staff, students, or visitors but may also result in legal consequences.

3. Administrative Organization for Radiation Safety Program

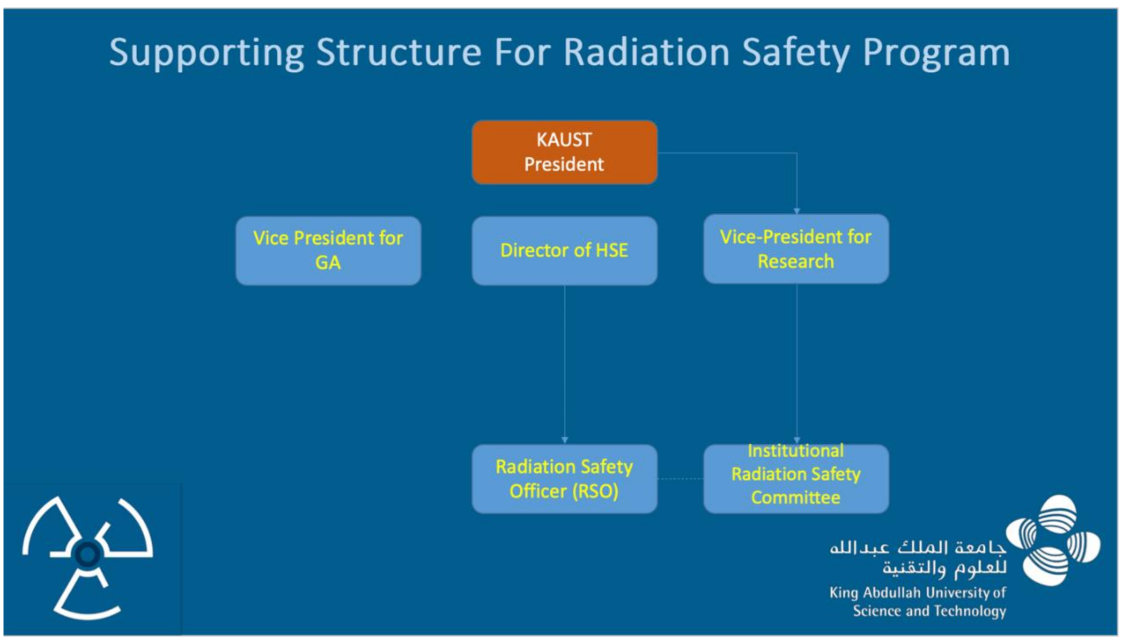
3.1. President of KAUST

The NRRC considers the University President as the **Authorized Person** who has been granted authorization under NRRC regulations and Laws to use, manage or operate radiation sources or nuclear materials within a facility. Under the regulatory framework, the prime responsibility for safety and security of nuclear and radioactive materials protection and safety throughout the lifetime of the practice lies with the authorized person and cannot be delegated.

The President has delegated functional responsibilities and authority in matters pertaining to campus radiation safety to the following university officials and staff as identified in the supporting structure for radiation safety program (Fig.1):

- The Vice President for Government Affairs (VPG)
- The Vice President for Research (VPR)
- The Director of Health, Safety, and Environment (HSE)

Fig.1 Supporting Structure for Radiation Safety Program



The general responsibilities of the President of the University as the authorized person are listed in Table 1, (Annex-III of the NRRC safety Guide NRRC-SG-020).

Table 1. Role and Responsibilities of the Authorized Person

General Responsibilities of the President of KAUST as the Authorized Person
a. Ensure safe use of ionizing radiations at facility premises.
b. Ensure that for all workers, occupational exposures are limited as specified by the NRRC and promptly report to NRRC if any relevant dose limits are exceeded;
c. Ensure that only workers who are designated in application by name and qualification credentials, as having key assignments related to protection and safety, operation or transport/handling are permitted to undertake and fulfill such required assignments and tasks;
d. Ensure that all radiation workers including female workers are aware of hazards associated with their work and their obligations and responsibilities;
e. Ensure that, under normal operational conditions, the dose limits for persons under 18 years of age are complied with.
f. Ensure compliance and implementation of the Commission laws, local rules, and procedures;
g. Designate a RSO and facilitate the functional role as defined by NRRC;
h. Establish and ensure implementation of policies and procedures to maintain radiation exposures ALARA;
i. Ensure that suitable and adequate facilities for protection and safety are provided to radiation workers including personal protective items and radiation monitoring equipment;
j. Ensure that requirements related to safety culture are being implemented;
k. Ensure arrangements for initial and continuous health surveillance of radiation workers;
l. Ensure training and retraining of radiation workers;
m. Ensure that necessary arrangements for the consultation of and co-operation with workers to ensure the effective implementation of the regulatory requirements for protection and safety are in place;
n. Ensure that necessary arrangements related to the control of outside workers are in place;
o. Record any report received from a worker regarding unsafe conditions or circumstances and take appropriate remedial action;
p. Devise a mechanism to refrain the workers from any willful action that could put themselves/others in situations that are harmful and contravene the regulatory requirements; and
q. Ensure integration of management system and radiation protection program so that safety may not be compromised due to equipment/packages malfunction.

While the University President holds the ultimate responsibility as the authorized person for radiation protection on campus, this responsibility is not a solitary burden. To ensure a comprehensive and effective radiation safety program, the President is supported by a dedicated team.

The Office of Government Affairs plays a vital role in maintaining compliance with the NRRC regulations regarding the use of radiation sources and materials. They act as the bridge between the university and regulatory bodies in coordination with the Radiation Safety Officer (RSO), ensuring adherence to legal requirements and safeguarding the university's operating license.

The Office of Research steps in to oversee research projects that utilize radioactive materials. They ensure these projects are conducted following established protocols, safeguarding the safety of researchers and the integrity of the research itself. This is accomplished through the Institutional Radiation Safety Committee (IRSC) and the Radiation.

Finally, the Health, Safety, and Environment (HSE) department provides on-the-ground expertise. HSE conducts inspections to identify any potential safety hazards, monitors radiation levels to ensure they remain within safe limits, and offers training programs to faculty, staff, and students who work with radioactive materials. This comprehensive approach empowers everyone involved to handle radioactive materials responsibly, minimizing the risk of accidents or exposures. This is accomplished through the Radiation Safety Officer (RSO).

In essence, the President's leadership as the authorized person is complemented by the expertise of the Office of Government Affairs, the Office of Research, and the HSE department. This collaborative effort fosters a culture of radiation safety within the university, protecting the health and safety of the university community and upholding the university's commitment to responsible research practices.

3.2. The Vice President for Government Affairs

The VP for Government Affairs (VPG) has been delegated by KAUST’s president as the responsible person for the radiation license application and all official communications with the NRRC in related matter.

3.3. The Vice President for Research

The VP for Research (VPR) has been delegated by the president as the responsible official for governance and oversight of the RSP. This is in part accomplished by the appointing members of the IRSC and its chair, reviewing reports provided by the IRSC, and assisting in accomplishing its goals and mission.

The responsible official must be kept informed of the status of the RSP and issues that may be raised to his/her attention by the IRSC, RSO or Director of HSE.

3.4. Director of Health, Safety, and Environment

HSE implements the campus RSP and ensures regulatory compliance and safety in the use of radiation and radioactive materials. The program includes audits of all authorizations for the use of radionuclides and Radiation Producing Equipment (RPE).

3.5. Institutional Radiation Safety Committee (IRSC)

The Institutional Radiation Safety Committee (IRSC) is a faculty-led group of individuals charged with ensuring the appropriate use of ionizing radiation-producing equipment and radioisotopes in research. The committee has oversight over all KAUST research activities involving ionizing radiation-producing equipment and radioisotopes occurring both on the academic campus and in the field.

The IRSC is composed of faculty members and individuals representing administrative and service functions who have been appointed by the responsible official.

The responsibilities of the radiation safety committee should include, but not be limited to:

- Regular review of all aspects of the radiation protection program;
- Review of occupational radiation doses and any accident reports prepared by the RSO;
- Making recommendations for improvements in the RPP;
- Provision of guidance and direction on the performance of the RSO's duties; and
- Preparation and dissemination of regular reports to all staff about relevant radiation safety issues.
- Other duties as set out in the committee Charter.

3.6. Radiation Safety Officer (RSO)

The primary RSO must be a subject-matter expert in radiation safety and protection and meet competency requirements of NRRC before being appointed by the authorized person. The primary radiation safety officer is responsible in implementing and ensuring the KAUST Radiation Safety Program is fully compliance to regulatory requirements, the authority to enforce policies and procedures established under the RSP in order to meet all regulatory requirements.

The RSO is responsible for all aspects of radiation control at KAUST, and has the authority to terminate any unsafe work practices that have or may potentially have a negative impact on the health and safety of any person. The RSO is part of the HSE department and actively contributes to the IRSC as a voting member. He/she carries out directives of the committee, refers matters to the committee for review and approval, and reports to the committee on the overall status of the radiation safety program.

The role of the RSO is to provide specialized guidance, consultation, and assistance to the research group, radiation users, and other university departments.

- Drawing up the overall framework of the RSP and supervising its implementation;

- Implementing the policies and procedures approved by the IRSC;
- Ensuring that all activities involving the use of ionizing radiation are performed in compliance with the University RSP and applicable national regulations;
- Reviewing proposals for use of ionizing radiation;
- Providing review and recommendations on the Radiation Use Authorization (RUA) applications for use of ionizing radiation (e.g. radioactive substances and radiation-producing equipment);
- Advising Radiation Use Authorization (RUA) holders and users on implementation of all aspects of the RSP, e.g. establishment of Local Rules, Standard Operating Procedures (SOPs), etc.;
- Supervise the transport of radioactive materials shipments from Airport customs to KAUST;
- Monitor all procurement and shipment of radioactive substances;
- Suspending the use of ionizing radiation if unsafe or unacceptable conditions exist. The IRSC will be notified within 24 hours of such a suspension to determine the necessary course of action.
- Monitoring selected individuals using ionizing radiation and public exposure levels;
- Auditing on an annual basis laboratories using ionizing radiation to assess compliance with the RSP, SOP, Local Rules, etc.;
- Maintaining an up-to-date inventory of all sources of ionizing radiation available at KAUST;
- Provide training to users on the potential health hazard, effective use of radiation monitors and detectors, procedures required to minimize exposure to radiation, and their responsibility to promptly report any conditions that may cause unnecessary exposures;
- Submitting an annual progress report to the IRSC;
- Investigating adverse events (accidents and injuries) and advising on required actions and reporting to the IRSC any significant problem, non-compliance or radiation-safety related incidents;
- Overseeing training of individuals using ionizing radiation.

Attention

- ❖ The RSO is empowered with the authority to cease any radiation work as deemed unsafe in accordance with the following regulations:
  - NRRC-SG-020 *Development of Radiation Protection Program*
  - NRRC-R-01 *Radiation Safety*

- ❖ The RSO has been delegated by the IRSC to halt any radiation-related activity that does not adhere to the university's IRSC policies.

3.7. Backup Radiation Safety Officer

During the Primary RSO's absence, a backup RSO is designated as a contingency plan to carry on the licensed activities and ensure that continuous oversight of the RSP is maintained. The backup RSO can also be involved in the day-to-day management of the RSP in coordination with the RSO.

For short-term absences, such as vacation, illness, or injury, the backup RSO should, at a minimum, know the regulatory requirements of the licensed activity and all reporting requirements.

4. Individual Responsibilities

4.1. Authorized Users

The Authorized User is a KAUST faculty or a department leader of KAUST Core Labs who has applied for and received Radiation Use Authorization (RUA) from the IRSC to use radioactive substances and/or radiation-producing equipment for research applications. Each RUA holder has the overall responsibility for application of radiation safety measures within his/her laboratory and is directly responsible for:

- Completing a RUA application form to use radioactive substances and/or radiation-producing equipment and submitting the form to Research Compliance.
- Consider other hazards (e.g. biological, chemical, electrical, etc.) associated with the use of ionizing radiation and refer to the associated manuals;
- Developing Local Rules and Standard Operating Procedures (SOPs) for the safe use of radioactive substances and/or radiation-producing equipment and ensuring compliance with these rules and procedures;
- Ensuring that those working under his/her RUA have completed required radiation safety training and are registered as “radiation workers/users”. The RUA holder must keep a record of all radiation users training;
- Contacting Research Compliance before:
    - Changes in the RUA (e.g. change in the experiments, change of location, add new radioactive materials, etc.).
    - Stopping the use of ionizing radiation.
    - Leaving KAUST for final exit.
- Keep exposure to radiation ALARA;
- Ensuring that all routine quality control tests are carried out as required by the manufacturers of the radiation related research equipment and national regulations;
- Enforcing the proper use of all safety equipment as specified in the Local Rules (e.g. personal monitoring, survey meters, Personal Protective Equipment, etc.);
- Ensuring that there are enough Personal Protective Equipment (PPE) for all users (i.e. gloves, safety glasses, lab coat, etc.) and that they are maintained and used appropriately;
- Ensuring that disposal of all radioactive substances is performed in accordance with approved procedures (see section 9);

- Notifying the RSO in case of:

– Unsafe conditions in the laboratory, radioactive spills and or suspected radiation related incidents.

– A registered user is leaving KAUST.

- Plan adequately for experiments and accurately determine the type and quantity of radioactive material to be used;
- Secure radioisotopes in their possession from unauthorized use;
- Record the receipt, transfer and disposal of radioactive materials in their area. The PI should submit radioactive material inventory data on a regular basis as requested by the RSO.

4.2. Radiation Workers/Users

Individuals other than the authorized user who work primarily under one RUA for an extended period and routinely use radiation sources (e.g., Research scientists, graduate students, postdoctoral fellows, laboratory technicians) will be designated as “Radiation Worker/User”. The authorized user must notify the RSO before new members are permitted to work with radiation sources.

Graduate students, postdoctoral fellows, laboratory staff working with radioactive materials or radiation-producing devices need to register as radiation workers, attend appropriate training for the research or work being performed and acquire badging as appropriate. To register as a radiation worker, the Authorized User must include the name of the worker and training record in *the radiation workers registration list* upon submitting the RUA application and update the list thereafter. Each radiation worker is responsible for their own safety and the safety of those around them, and is responsible for:

- Ensuring they have completed the required training for radiation safety (online or live course and laboratory specific training) and are registered as “radiation worker”.
- Complying with all established safety rules detailed in the Radiation Safety Manual, Local Rules and other applicable policies and procedures.
- Wearing appropriate PPE as necessary.
- Ensuring that any other persons that can be potentially exposed are also wearing appropriate PPE if necessary.
- Using all available safety controls (e.g. shielding, interlocks, etc.) to keep radiation exposure ALARA.
- Ensuring that radioactive substances are secured (e.g. by locking them away in the laboratory when not in use).

- Notifying the RUA holder, RSO and possibly the Lab Safety Representative (LSR) of unsafe conditions in the laboratory, and all known or suspected radiation related accident.

There are two categories of Radiation Workers:

i. Classified Radiation Workers

Radiation workers who are working in a controlled area and are likely to receive an effective dose of ionizing radiation in excess of 6 mSv per year or an equivalent dose in excess of 3/10^{ths} of any relevant dose limit. These users will be made subject to medical surveillance to ensure that they are certified fit to work with ionizing radiation and have their doses appropriately assessed and recorded (Section 52, NRRC-R-01; Section 4.14, NRRC-SG-020).

ii. Non-Classified Radiation Workers

Users who, as a result of their work activities, are not likely to receive a dose of ionizing radiation which exceeds 6 mSv per year but may receive a dose exceeding 1 mSv per year

Most of KAUST's work with radiation is low-risk and the risk of over exposure is negligible. The university strives to maintain whole-body effective doses below 1mSv per year, therefore, most staff and students working with ionizing radiation at KAUST are categorized as **Non-Classified Radiation Workers**.

4.3. Radiation Labeling Core Lab (RLCL)

The Radiation Labeling Core Laboratory (RLCL) is KAUST's sole facility to support scientific experiments involving unsealed radioactive substances, however, under special conditions; the IRSC may permit some labs to use exempt quantities of uranium salts such as uranyl acetate or uranyl nitrate solutions for scanning electron microscopy (SEM) sample preparation. It conforms to radiation protection regulations of KSA and observes International Atomic Energy Agency (IAEA) guidelines, adhering to international standards of radiation safety. In addition, RLCL is Biosafety Level 2 (BSL-2) compliant facility. The RLCL is designed as a general bioscience/chemistry lab with some specialized equipment, including a radioisotope fume hood, cold storage units (-80 C, -20 C, and +5 C), liquid scintillation counters (LSC), and radiation survey instruments. It implements all necessary administrative and engineering control measures, such as proper shielding and work procedures, to ensure safety with respect to radiation hazards. In addition, radiation survey, dosimetry, and monitoring are performed in accordance to KAUST HSE radiation safety requirements. The facility manages radioactive waste streams, receiving of radioactive materials, storage, and security of radioactive chemical inventories. The RLCL is run and supported by KAUST Core Lab staff.

4.4. Visitors

Visitors are individuals entering the laboratory who are not radiation users and who do not directly work with ionizing radiation (i.e. they do not handle radioactive substances or work with radiation-producing equipment). These individuals are considered as general members of the public and must be authorized to enter by the responsible RSO, RUA holder or RLCL management. The visitors must always be accompanied by an authorized user and adhere to all applicable KAUST safety procedures (e.g., wear PPE, etc.).

4.5. Ancillary Personnel

Ancillary personnel include those individuals (KAUST staff, maintenance, administrative, contractors, etc.) who are assigned to perform work on KAUST research spaces, but who are not working directly with ionizing radiation. As a result, for the purpose of establishing radiation exposure limits, these workers are considered as general members of the public. However, they shall adhere to safety procedures detailed in this manual. Access to these areas may need to be under supervision of authorized users, especially when entering a laboratory where radioactive substances are used.

5. Radiation Use Authorization (RUA) Application

Authorization to purchase, store, and use of any source of ionizing radiation must be obtained from the IRSC. Trained and experienced PIs who are qualified to supervise the use of radiation sources at KAUST can be designated by the IRSC as **Authorized Users**. To become an Authorized User, a faculty member must submit a RUA application to the IRSC.

The written authorization to use sources of ionizing radiation is referred to as a ***Radiation Use Authorization*** (RUA) and is an important component of the KAUST RSP. All documentation and information regarding RUAs are available on the research compliance webpage.

Note that while the IRSC grants approval of all RUA applications, it delegates its responsibility to the RSO for some radiation-producing equipment that are considered safe (see Table 4.1).

Table 4.1. Person/body responsible for approval of RUA at KAUST.

Type of radiation sources	Body/person granting the RUA
Radiation-producing equipment emitting X-rays with energy **below or equal** to 50 kV	RSO *(Under delegation from IRSC)*
Radiation-producing equipment emitting X-rays with energy **higher than** 50 kV	IRSC
Radiation-producing equipment with open X-ray beam *(i.e., Portable X-ray diffraction analysis system)*	IRSC
Equipment containing sealed sources (Gas chromatograph, liquid scintillation counter, etc.)	RSO *(Under delegation from IRSC)*
Radioactive sealed sources for calibration	RSO *(Under delegation from IRSC)*
Radioactive substances (Unsealed sources)	IRSC
Others	IRSC

5.1. Application Responsibilities and Requirements of the Authorized User (A.K.A. RUA Holder)

The RUA holder is responsible for:

i. Safe use of the radiation source(s) and
ii. Complying with the contents of the Radiation Safety Manual, the provisions and requirements of the NRRC Technical Radiation Safety Regulation (NRRC-R-01), and the university general radiation license.
iii. Ensuring that all persons working under his/her supervision have received proper radiation safety training and are aware of the radiation hazards associated with their activities.
iv. Ensuring all persons working under his/ her supervision observe the guidelines and procedures outlined in the KAUST Radiation Safety Manual.

5.2. Applying for a RUA

Requests for use of radioactive materials and/or radiation producing equipment (RPE) are initiated by the prospective PI by submitting the applicable application documents. These requests are processed as follows:

A. RUA for Working with X-ray Radiation Producing Equipment

For new X-ray producing devices, the PI must request a purchase approval from the IRSC before applying for a RUA (see section 5). To apply for a new RUA, the PI must submit an *RUA-RPE application form* to the IRSC via IRSC@kaust.edu.sa or to the RSO via hse@kaust.edu.sa . As part of the application, the authorized user must ensure that the following documentations are submitted:

i. **Completed and signed RUA Application Form** (**RUA-RPE**)
ii. **Standard Operating Procedures (SOP)** - *this document details how to use and operate the equipment including emergency procedures.*
iii. **Local Safety Rules** - this document provides all the safety information related to the equipment such as RSO contact details, dosimetry requirement, safety measures in place (e.g. equipment is shielded, equipment has interlocks, etc.) and emergency procedures. Templates are available on the research compliance webpage or can be requested from the RSO.
iv. **Radiation users list –** *list names of users who will be working on the equipment and their training documentations*.
v. **RSO radiation survey report** – *radiation monitoring for X-ray leakage. This is done during installation and commissioning of the equipment.*
vi. **Radiation equipment Purchase approval (for X-ray producing equipment) –** radiation risk assessment of the proposed device.

B. RUA for Using and Procurement of Radioactive Material (including equipment containing sealed sources)

The PI must submit an *RUA-RAM application* form to the IRSC via IRSC@kaust.edu.sa or to the RSO via hse@kaust.edu.sa . As part of the application, the authorized user must ensure that the following documentations are submitted:

i. **Completed and signed RUA Application Form (RUA-RAM)**
ii. **Standard Operating Procedures (SOP)** - this document details experimental protocols, Isotope(s), amount(s), and form(s) proposed for the experiment or project. This information will be reviewed by the RSO to ensure that the University does not exceed the quantity specified in the KAUST license. If the amount desired will cause the University to exceed the amount specified in the General Radiation License, a request for a license amendment will have to be made to the NRRC to proceed with the authorization. This will lengthen the time to approve the RUA.
iii. **Local Safety Rules** - this document provides all the safety information such as radiation risk assessment of the experiment, Anticipated radiation levels and release

of radioactive material to the laboratory/natural environment, Proposed monitoring instruments/procedures to be used, proposed radioactive waste handling/disposal protocols, location floor plan, RSO contact details, dosimetry requirement, radiation protection measures in place, and emergency procedures. Templates are available on the research compliance webpage

iv. **Radiation users list** (Require completing *Radiation Worker Registration or authorized users list form*)

Note:

Once a RUA has been approved, the RUA holder is allowed to purchase radioactive substances (more details in section 5). The RUA holder must ensure that only the authorized radionuclides in the RUA are purchased. In addition, the RUA holder for unsealed radioactive substances (other than uranyl compounds) in collaboration with the RSO and the RLCL management must ensure that the total activity held under the RUA (this includes new purchased stock, current stock, current radioactivity used as part of an experiment and waste that has not been transferred to the RLCL management) remains within the RUA limits. For more details, please refer to the *Purchase and RUA application procedure for stand-alone sealed sources and unsealed radioactive substances SOP.*

5.3. Process for Submitting an RUA Application

1. Complete and sign the **RUA application**. The application must provide sufficient information to enable safety analysis and prescription of adequate precautions. Instructions to prepare a RUA may be obtained from RSO.

2. Submit the application with all related documentation to the RSO.

3. The RSO will review the request, review the proposed facilities, obtain additional information if necessary, and submit the RUA to the IRSC.

4. The RSO is delegated by the IRSC to approve only equipment with maximum energy below 50 kV as well as equipment containing sealed sources within 10 days of the receipt of the application.

5. The IRSC shall review the request, the safety review, and the proposed authorization. It may obtain additional information and approve, modify, or deny the proposed authorization. Approvals will be issued based on the type of work that applicant is seeking authorization to do.

6. The IRSC sends RUA letter of approval to the PI/responsible person through Research Compliance.

7. If an application is rejected or needs to be amended, the IRSC notifies the PI or the designated responsible person in writing and provides the grounds for the decision.

8. After the RUA is issued, the RSO visits the lab and ensures that all radiation safety requirements are implemented.

9. Applicants approved to use radioactive materials will be contacted by RSO, who will conduct an initial radiation safety inspection to assist the new Authorized User with his/her lab set up.

Fig.4.1 and Fig.4.2 summarized the RUA process for radiation producing equipment and radioactive materials.

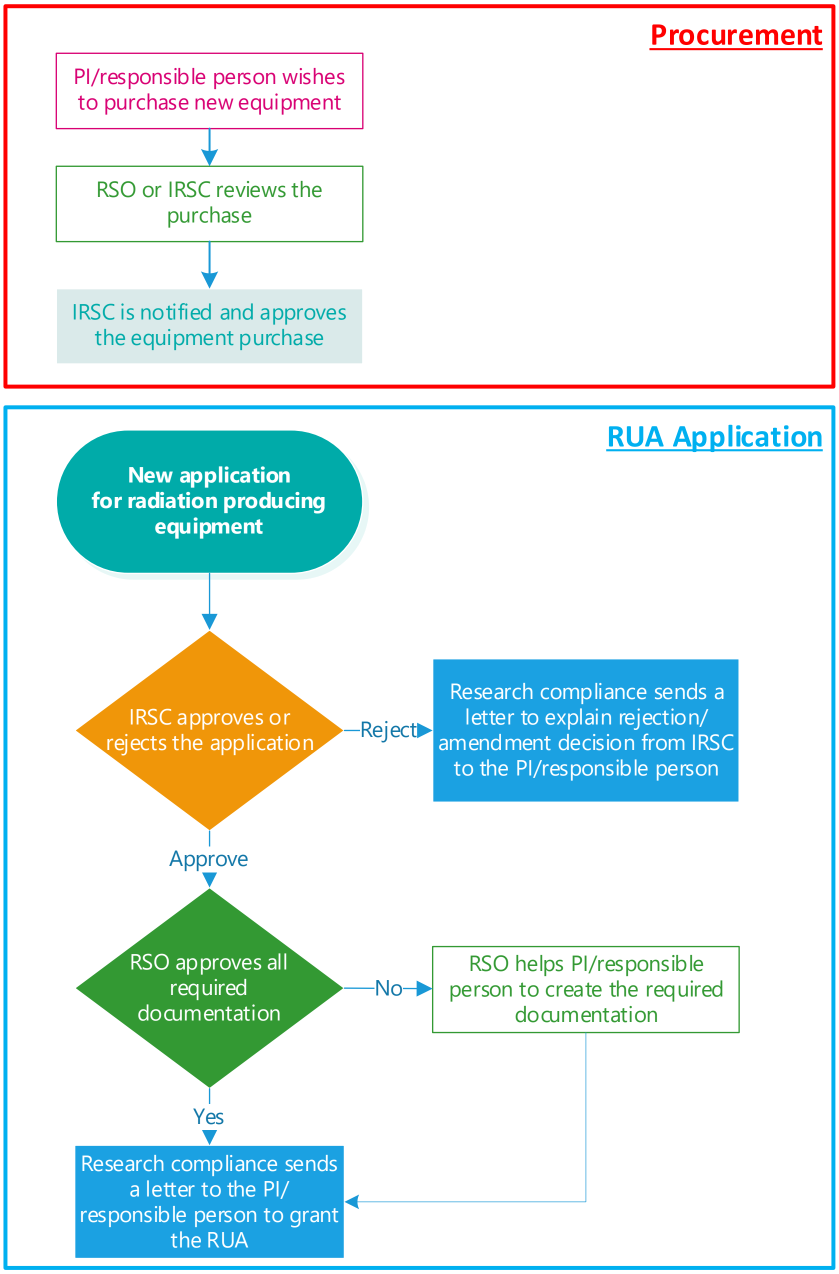


Figure 4.1. RUA application process for radiation-producing equipment

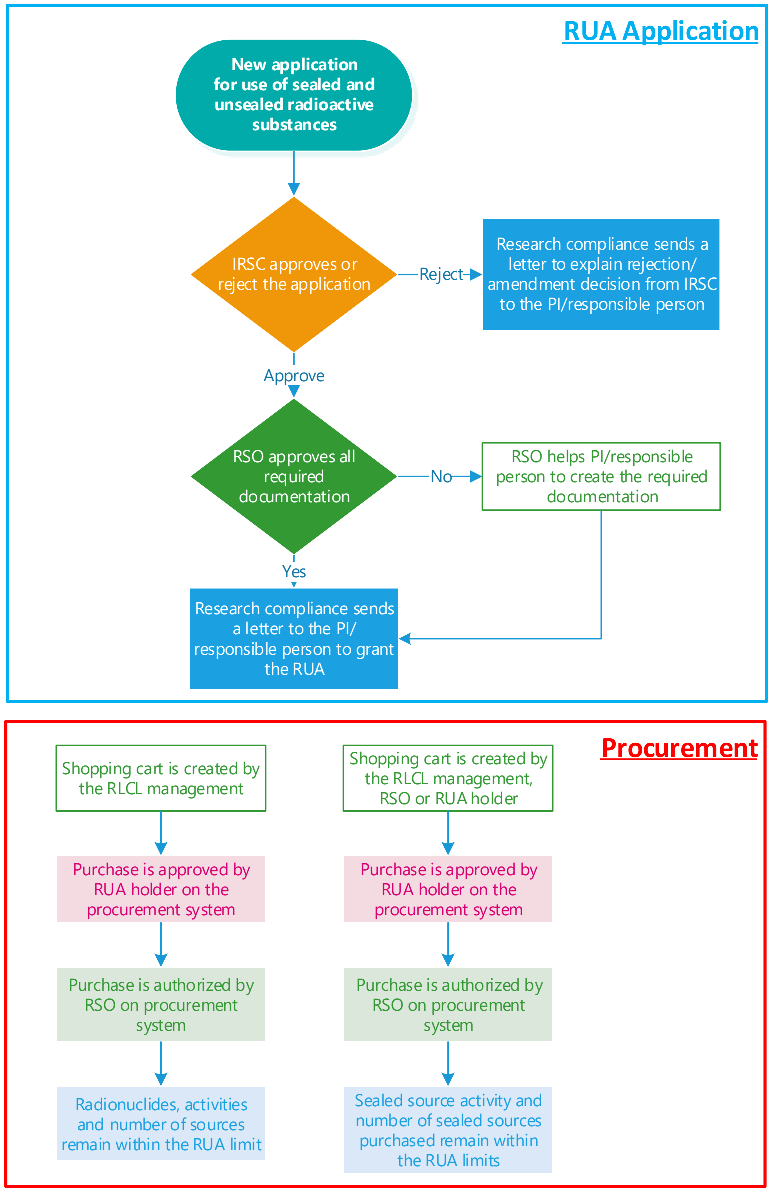


Figure 4.2. RUA application process for stand-alone sealed sources and unsealed radioactive substances.

5.4. Renewal

The RUA for X-ray producing equipment has no expiration day and is valid as long as the equipment is in use by the RUA holder. The RUA for radioactive materials is valid for a period of 3 years and must be renewed using the forms available on the research compliance webpage. The RUA holder will be contacted by research compliance at least two months before the RUA’s expiration date. The RUA holder must then fill the renewal application form and submit it to the research compliance team. The renewal process includes an assessment of users training, laboratory compliance history, instrument calibrations, and records. Based on this review, the IRSC grants renewal or conditional renewal. If the renewal is conditional, the RUA holder has a specific period of time to address the requirements. Once the renewal is approved, the IRSC sends the renewed RUA to the RUA holder.

5.5. Amendments

In certain cases, a RUA holder may need to amend the RUA application. Such instances include changes in room locations, modifications in the activity and/or type of radioactive substances, alteration of a device, or other significant changes. Amendments to a RUA application must be submitted to IRSC@kaust.edu.sa and are processed as described in section 3.1.

5.6. Termination

A RUA may be terminated when a RUA holder decides to stop work involving the use of ionizing radiation sources. In this case, the RUA holder must notify the research compliance team in advance (by email to IRSC@kaust.edu.sa), at least 30 days, in order to permit scheduling of transfer functions.

For radiation-producing equipment or equipment containing sealed sources, the RUA holder must notify the RSO before transferring the ownership of the equipment to another PI (who needs to apply for an RUA before using the equipment) or the disposal if the equipment is not needed. For the latter, an asset disposal form must be completed in coordination with the RSO and Research Asset Management.

For unsealed radioactive sources, if the remaining stock cannot be used by other RUA holders it is disposed as waste; however, if the remaining stock can be used by other RUA holders in the future, the remaining stock may be transferred to the hazardous waste building under the RSO supervision and stored securely in the radioactive materials storage room.

5.7. Suspension

A RUA may be suspended following non-compliance of safety rules or dangerous activity involving the use of ionizing radiation by the IRSC. Examples of non-compliance resulting in suspension of the work with ionizing radiation are:

- Misuse of sources of ionizing radiation that has or could result in unintended exposure to ionizing radiation to a user, staff or member of public;
- Intentionally disabling or removing safety interlocks;
- Operating a radiation-producing equipment or using radioactive substances without an RUA;
- Use of ionizing radiation in a location not approved on the RUA;
- Use of ionizing radiation by non-authorized users;
- Failure to obtain the required training.
- Failure to report a radiation incident to the RSO.
- Failure to comply with the KAUST radiation safety procedures and RSO instructions.
- In case of non-compliance, the IRSC or RSO under delegation from the IRSC informs the RUA holder and requires him/her to take remedial actions. The RUA holder will have a defined time period, which will depend on the severity of the non-compliance, to address the remedial actions.
- If after the defined time-period, the actions have not been completed, the IRSC may suspend the license and inform the RUA holder as well as the Dean or facility manager. The RUA will only be re-instated following review of the completed actions by the RSO and approval by the IRSC.
- If after the defined time-period, all actions have been completed, the IRSC will reinstate the RUA by sending a formal letter to the RUA holder as well as the Dean or facility manager.

5.8. Use of Radiation in Animals and Plants

In addition to the processes described above, if any research governed by the RSP will involve the use of animal or plants that will fall under the jurisdiction of the Institutional Animal Care and Use Committee (IACUC) or Institutional Biosafety and Ethics Committee (IBEC), approval from the relevant committee (IACUC or IBEC) is also required before work can commence.

6. Procurement, Receipt, and Transfer of Radiation Sources

6.1. Procurement Policy

KAUST is licensed by NRRC, the Competent Authority in Saudi Arabia, to possess and use radioactive substances and radiation-producing equipment for research applications.

6.2. Procurement and delivery of radiation-producing equipment and equipment containing sealed sources

For acquisition of new radiation-producing equipment or equipment containing sealed sources, prior purchase approval must be granted by the IRSC (or the RSO under delegation from the IRSC) and this will be done via the Funding Proposal for Scientific Equipment (for equipment above $20K) or via shopping cart approval for equipment less than $20K.

Once the purchase has been approved by the IRSC as well as ASEPC or via the procurement system, the PI/responsible person must apply for a RUA in order to be allowed to use the source of ionizing radiation (see section 4).

For more detailed information, please refer to the *Radiation Equipment Purchase Procedure*.

Shipment of radiation-producing equipment will be delivered directly to the lab. Upon delivery, the device shall be installed, accepted, and commissioned by the manufacturer or authorized agents in coordination with the RSO. The RUA holder must also notify the RSO when the device is on-site and when it is installed.

6.3. Procurement and delivery of radioactive materials

Procurement of stand-alone sealed sources and unsealed radioactive substances (i.e. single orders or multiples orders) can only occur with a valid RUA and is done via the current procurement system. Following approval of the shopping cart by the RUA holder, the procurement team requests approval from the RSO before completing the purchase order. Please note that for the purchase of unsealed sources, the order will be placed by the RLCL management upon request from the RUA holder.

All shipments of stand-alone sealed sources and unsealed radioactive substances is picked up by a licensed carrier at the airport and delivered to the Radiation Labeling Core Lab (RLCL) or the designated radioactive material storage area in the radioactive waste bay directly (see section 9.1).

For more information, please refer to *the Procurement of Radioactive Material Procedure*.

6.4. Custody of radioactive substances and/or radiation-producing equipment

The RUA holders are responsible for the custody of all radiation-producing equipment and sealed sources in their possession. They must also ensure that all devices in their possession are secure from unauthorized use or removal. Regarding the custody of unsealed radioactive substances, the RUA holder shares the responsibility with RLCL management. The RUA holder is responsible for providing the detailed information on the RUA application form, requesting the purchase of the required radionuclides to the RLCL management, designing and conduction the experiment, ensuring that the waste generated from the experiment is packaged according to the RLCL procedures. The RLCL management is responsible for ordering the stocks, ensuring secure storage of the stocks, auditing the usage of radionuclides in the RLCL, packaging the waste to be ready for pick up by the RSO or staff authorized by the RSO, reporting any concern regarding safety issues in the RLCL, carrying out regular contamination monitoring, ensuring all users working in the RLCL are authorized, etc.

Attention

- The Radiation Safety Officer (RSO) must be immediately notified of the suspected loss or loss of any sources of ionizing radiation.
- Equipment containing sealed radioactive sources must be registered and approved by the IRSC. Any equipment containing radioactive sources will be suspended by the RSO if it is found that it does not comply with KAUST's Radiation License and IRSC's policies.
- The unauthorized transfer of radioactive material within KAUST research spaces will result in the suspension of the RUA and impoundment of the materials.
- Records of each transfer/shipment will be maintained by the Radiation Safety Officer. The Authorized User is also required to maintain records of the transfer and to adjust the inventory records accordingly.

6.5. Transferring and Shipping of Radiation Sources

All transfers of radioactive substances or radiation producing equipment must be specifically approved by the RSO.

Transfer within KAUST research spaces

Radiation-producing equipment or equipment containing sealed sources may be transferred within KAUST research spaces. Note that the RSO must be informed before organizing the transfer of the equipment (see section 3.9).

Individuals working with radioactive materials are not allowed to transfer stand-alone sealed sources or unsealed radioactive substances within KAUST research spaces unless they have obtained approval from the RSO.

Transfer outside KAUST research spaces

A. Radiation Producing Equipment

Radiation producing equipment may be transferred outside KAUST research spaces, provided full coordination of Asset management and Asset support team with the RSO and completing *the HSE X-ray transfer and disposal form*. The Procurement department shall request the receiver/buyer to provide a letter of authorization to use radiation produced equipment approved by the competent authority in their country before proceeding with the transfer process.

B. Radioactive Material

Transfer of radioactive materials within Saudi Arabia are regulated by the NRRC regulations and are allowed after the approval of the RSO as long as the shipment is transported by an authorized transportation company and the receiving institution has a valid radiation practice license. On the other hand, shipping of radioactive material outside the country is allowed only for radioactive waste, through proper arrangement with the RSO, NRRC and General Security.

7. Classification of Areas

Designated areas are established for the purpose of protecting personnel, members of the public and property from accidental contamination and unnecessary radiation exposure. Each individual working or visiting such areas must carefully observe warning signs and notices. Classification is based on an assessment of the expected annual dose limits, the probability and magnitude of potential exposures, and the type and extent of the procedures required for protection and safety.

The purpose of classification of areas is to help manage the radiation risk by identifying and segregating higher risk activities from the lower, and thus controlling the extent of radiation exposure. The higher category is the Controlled Area, and thus tighter controls will be required in Controlled Areas than in Supervised Areas. The following table gives some examples of the difference in control measures in between the types of areas:

7.1. Controlled Area

A Controlled Area is defined as an area in which specific protection measures and safety provisions are or could be required for controlling exposures or preventing the spread of contamination in normal working conditions and preventing or limiting the extent of potential exposures. In a controlled area, there is a likelihood of receiving an effective dose greater than 6 mSv in a year or an equivalent dose greater than three tenths of the relevant dose limit as pre-scribed in Regulation on Radiation Safety (NRRC-R-01). In addition, in such an area the external dose rate may be equal or above 3 μSv/h (this would correspond to an annual dose of 6 mSv assuming 2000-hours working year).

The Controlled Area must be surrounded by a physical barrier (e.g. wall or warning tape) when the radiation source is used. Access to the Controlled Area must be restricted to classified radiation workers only, by use of engineering controls and/or administrative means (e.g. proximity access, door lock, etc.). The entrances to the Controlled Area must be marked with a warning notice (the notice must state that the area is designated as ‘Controlled Area’, it must also include precise information such as ‘X-ray radiation’ or ‘unsealed sources’ to alert employees of the risk, and incorporate a radiation trefoil sign, see Figure 3a) and if possible, a warning light placed at eye level. Individuals working in Controlled Areas must be monitored and personal protective equipment must be available. In addition, an area radiation monitoring program must be in place to evaluate and review working condition periodically. (Ref.NRRC-SG-020).

7.2. Supervised Area

Any area of the facility should be designated as a supervised area where there is a likelihood of receiving an effective dose greater than 1 mSv in a year or an equivalent dose greater than one tenth of the relevant dose limit as prescribed in Regulation on Radiation Safety (NRRC-R-01).A Supervised Area is an area in which radiation protection measures need to be followed and reviewed, to ensure it does not need to become a Controlled Area. In addition, in such area the external dose rate may be equal or above 0.5 µSv/h but no more than 3 µSv/h.

The Supervised Area must be surrounded by appropriate barrier device (e.g. wall or warning tape). The entrances to the Supervised Area must be marked with a warning notice (the notice must state that the area is designated as 'Supervised Area', it must also include precise information such as 'X-ray radiation' or 'unsealed sources' to alert employees of the risk, and incorporate a radiation trefoil sign, see Figure 3b). Only authorized users and registered radiation workers are allowed to use radiation sources, but non-authorized users can work in the surrounding area. Radiation area monitoring must be carried out to ensure that radiation dose levels are kept ALARA; additionally, individuals working in Supervised Areas may be monitored as deemed by the RSO. The status inside the Supervised Area must be reviewed periodically for determining the need for more effective protection and safety procedures, or for changing the designation of the area.

The RLCL as well as laboratories using Uranyl Acetate in which unsealed radioactive substances work takes place at KAUST are designated as Supervised Areas. Other examples include laboratories equipped with computerized tomography equipment and X-ray irradiator.

7.3. Non-Designated Work Area

In this area no contamination or exposure to significant radiation levels exist, thus, personal monitoring is not required. Only authorized radiation workers are allowed to use the radiation-producing equipment or device containing sealed source, but non-authorized users can work in the surrounding area.

Warning notices are not required since the exposure rates from these devices is no greater than background; however, an area monitoring program must be in place to ensure radiation doses to staff working in the area do not exceed general public dose limits.

Laboratories using equipment contained sealed sources, electron microscopes and X-ray analysis equipment such as X-ray diffraction; X-ray photoelectron spectroscopy, etc., are defined as non-designated area.

The fact that an area is not designated means that the work is deemed unlikely to give rise to a radiation dose to any individual in excess of the annual radiation dose limit for members of the public.

Table. 6.1 Classified Areas comparison

Controlled Areas	Supervised Areas	Non-designated Areas
Restricted Access. Access only permitted to classified radiation workers or those entering in accordance with "suitable written arrangements"	Managed access by non-radiation workers permitted	No control on the access by non-radiation workers
Must be in a physically segregated area	Must be in a clearly demarcated area	No special segregation required
Access by cleaners not permitted	Managed access permitted	Access permitted
Required personal monitoring and periodic medical surveillance for radiation workers	No medical surveillance is required. Personal monitoring only required in certain circumstances	Personal monitoring unlikely to be required

(a) (b) (c)

Figure 6.1. Area Designation warning signs (a) Controlled Area, (b) Supervised Area, (c) X-ray radiation Supervised Area

8. Training

Individuals working directly with ionizing radiation must complete both an initial radiation safety training, which depends on the type of ionizing radiation source used (i.e., radioactive substances and radiation-producing equipment), and laboratory specific training. The latter must be provided by the RUA holder, or someone authorized to do so by the RUA holder. Both types of trainings must be documented, and records made available to HSE/RSO.

8.1. Required Training for Radiation Safety

Radiation safety training is mandatory for any user who is planning to use radiation sources or equipment in their experiment.

There are three different required training for radiation safety available at KAUST. Individuals must complete the training that corresponds to the work carried out in the laboratory (Table 7.1). All these trainings can be completed online (via SALUTE) or live (see Research Safety Training Calendar) and the person must take the associated quiz, which has a passing score of 80%. Note that for the "Radioactive Materials Safety Training" course, individuals will only be allowed one attempt at taking the course online via SALUTE. If the individual does not achieve the passing score of at least 80% on the first attempt, then they will be required to take the training course in a live training class.

Table 7.1 Training requirements for Radiation Safety.

Training	Who must take this training	Online and/or Live*
SEM and TEM Safety Training	Person working with electron microscopes (SEM, TEM, etc.).	Online
X-ray Analysis Equipment Safety Training	Person working with X-ray equipment (XRD, XRF, XPS, cabinet X-rays, CT, X-ray irradiator, portable XRF, etc.).	Online
Radioactive Materials Safety Training	Person working with sealed and unsealed radioactive substances.	Online or Live*

*Live training session schedule are available on: Radiation Safety Training Calendar.

8.2. Laboratory specific training

The required training for radiation safety must be supplemented with laboratory specific training. This training, which is performed by the RUA holder or other staff authorized to do so by the RUA holder, must cover practical use of ionizing radiation in the laboratory, especially regarding equipment use and protocols as well as practical safety precautions.

A record of the training must be kept by the RUA holder. The RUA holder can allow the individual to become a radiation user (i.e., allow to work with ionizing radiation) only after the user has passed both the required training for radiation safety and laboratory specific training.

8.3. Peripheral worker training

Laboratory personnel who do not work directly with ionizing radiation but in areas where ionizing radiation is used are not required to complete the required training for radiation safety or laboratory specific training. However, it is recommended that they receive awareness training under the guidance of the RUA holder. Indeed, it is the responsibility of the RUA holder to ensure that each individual working in his/her lab receives appropriate training based on their work functions with regard to radiological hazards. Please note that the RSO can assist/provide awareness training for these workers on demand.

8.4. Ancillary personnel training

Individuals (such as maintenance workers, housekeepers, Site Services, administrative workers, etc.) who are not ordinarily exposed to radiation or radiation producing machines in the course of their jobs, but whose duties may extend to areas of potential exposure. and require basic radiation safety training. The RSO can provide an awareness training for these workers that is available on demand only.

9. Dose Monitoring, Assessment and Recording

9.1. ALARA Principle

KAUST aims to prevent unnecessary radiation exposures to individuals and the environment, and to keep radiation exposures to employees, members of the public and the environment ALARA. The ALARA principles attempt to maintain exposures to radiation below the dose limits, consistent with the purpose for which the exposure is generated, but also taking into consideration the state of technology, the cost of the improvements needed to reduce the radiation exposure, and the benefits to public health and safety. As part of the ALARA program at KAUST, individuals who are less than 18 years old are not allowed to work with sources of ionizing radiation in Supervised or Controlled Areas and their radiation doses are equivalent to that of members of the public (see Table 4). Two basic conditions are considered necessary in any Radiation Safety Program for keeping occupational and public exposures ALARA:

1. **Management commitment to safety principles.**
2. **Safety culture, whereby users should always try to minimize radiation exposures.**

9.2. Occupational Doses

Radiation exposures to individuals working in Controlled or Supervised Areas (i.e. classified and non-classified radiation workers) are considered "occupational" exposures. The radiation dose in any one calendar year must be kept ALARA and specifically below the primary dose limit set by the Competent Authority (NRRC), see Table 8.1. In addition, radiation workers' doses should not exceed the dose constraint levels set by KAUST. The dose constraint level is not intended to be an absolute limit but to provide guidelines for keeping exposures ALARA. If the constraint dose levels are exceeded, an investigation by the RSO will be carried out and reported to the IRSC, and if necessary to the Competent Authority (NRRC). The investigation includes a dose estimation, and a review of the radiation safety measures to determine whether additional safety measures are required.

Table 8.1. Annual Occupational dose limits and Dose Constraints levels for individuals working at KAUST

	Occupational Annual Dose Limit (mSv/y)	Annual Doses above which classification would be necessary (mSv/y)	KAUST Dose Constraints[1]
Whole Body	20 (100 mSv/5y)	6	2 mSv/year
Lens of the eye	20	15	15 mSv/year
Skin or Extremities (hands and forearms, feet and ankles)	500	150	50 mSv/year

[1] Administrative Dose Constraints are dose equivalent recommendations adopted by the IRSC for all KAUST personnel, it meant to provide guidelines for keeping exposures ALARA. If the dose constraints are exceeded, a review by the Radiation Safety Officer is required to determine if additional safety measures are required.

9.3. Public (Non-Occupational) Doses

General public dose limits apply to members of the general public, peripheral workers, ancillary staff, and visitors. In addition, individuals working in Non-Designated Areas (i.e., non-classified workers) are also subjected to the general public dose limits since radiation-producing equipment used in these areas are not regulated by NRRC and considered safe (i.e., no exposure to significant radiation levels expected). All activities must be done in a manner that limits the exposure of these staff members as well as the general public to the regulatory limits for members of the public specified in Table 4. As for public doses, if the NRRC dose levels are exceeded an investigation by the RSO will be carried out and reported to the IRSC and if necessary to the Competent Authority.

Table 8.2. NRRC public dose limits

	Public dose limits set by NRRC
Whole Body	1 mSv/year
Lens of the eye	15 mSv
Skin or Extremities (hands and forearms, feet and ankles)	50 mSv

9.4. Pregnant workers

Any female radiation worker who is pregnant or believes that she may be pregnant should inform the RUA holder and/or the RSO as soon as possible. Although declaration of pregnancy is voluntary and all information relating to the pregnancy is strictly confidential, concerns about fetal exposure can only be addressed if known. Any female who is occupationally exposed to radiation resulting from research activities may declare her pregnancy and institute the enhanced protective measures by completing and submitting the Pregnancy Declaration Form. If a written declaration of pregnancy is not submitted, then the worker’s dose continues to be controlled under the normal dose limits for workers with ionizing radiation.

The dose limit to an embryo/fetus due to occupational exposure is 1 mSv from the declaration of pregnancy to the employer.

The RSO may be asked to review the declared pregnant woman’s potential exposures, and this may result in work modifications or temporary termination of work involving occupational radiation exposure after consulting with the affected woman’s supervisor, and/or the assignment of special dosimetry. However, for the type of radiation work performed at the KAUST, it is rarely necessary to recommend reassignment or changes to job duties to reduce exposure.

Additionally, the RSO is available to answer any questions users may have. All inquiries and information are kept strictly confidential.

9.5. Personal monitoring

The NRRC regulations requires personnel exposure monitoring for the following:

- Individual likely to receive in one year a dose in excess of 10% of the NRRC primary dose limits (see Table 8.1); this means any individual working in Controlled or Supervised Areas;
- Declared pregnant women working with sources of ionizing radiation likely to receive a radiation dose and is required to wear a personal dosimeter.

The amount of cumulative external radiation that a person has been exposed to can be determined using a wide variety of devices and materials. All of these are referred to as "dosimeters." Dosimeters are provided to track exposures to the extremities as well as the entire body. Dosimeters are quarterly swapped out by the RSO and sent to the vendor's laboratory for analysis.

(A) External Radiation Dose

Based on the RSO’s review, dosimetry requirements are determined and are indicated in the Local Rules. There are generally two types of external dosimetry:

- Whole-body monitoring for external radiation exposure - usually by Optically Stimulated Luminescence (OSL) or an equivalent badge worn on the waist or at chest level.
- Extremity monitoring (usually by ring dosimeter) worn on any finger and on the palm side of the most exposed hand.

When not being worn, dosimeters must be stored in a location where they are not exposed to radiation. Dosimetry will be provided and processed only by vendors accredited by the Competent Authority.

I. Dosimetry for work with enclosed radiation-producing equipment and/or instruments containing sealed source

Staff/students working with shielded radiation-producing equipment emitting X-ray as well as equipment containing shielded sealed sources are not expected to receive more than 1 mSv per year and therefore do not require personal dosimeter. The RSO performs annual area dose monitoring in the areas where the equipment is used as well as a semi-annual leak test of sealed sources in order to ensure that doses are kept ALARA.

II. Dosimetry for work with radiation-producing equipment that emit open X-rays beam

Staff/students working with radiation-producing equipment that emit open X-rays beam such as portable XRF, must be issued with ring dosimeters because of the potential risk of exposure. However, the use of ring dosimeters should not lessen any necessary engineering control measures to minimize radiation exposure.

III. Dosimetry for staff working with radioactive sources

Staff/students working with stand-alone sealed sources may require personal dosimetry badge and this will be decided by the RSO. Staff/students working with unsealed radioactive sources must be issued with personal dosimeters when working with high beta energy or gamma emitting isotopes. However, note that, personal dosimeters are not required when working with some radioactive substances such as H-3, C-14, S-35, P-33, because the energies and type of radiation emitted by these radioactive substances cannot be detected and thus dosimeters are not efficient.

(B) Internal Radiation Dose

Internal radiation dose occurs if radioactive substances are inhaled, ingested, injected, absorbed through wounds, or absorbed through the skin. Protective clothing and other measures must be used to prevent or reduce internal radiation dose.

The IRSC must review each RUA application before work can begin. One aspect of the IRSC's review is to determine the potential for internal exposure. The RSO determines what, if any, controls (such as use of a fume hood) are required and the need for bioassays. All these requirements must be included in the Local Rules. However, considering the quantities and activities of radioactive substances currently used in the laboratory, routine bioassays will not be necessary.

9.6. Proper use of Personal Dosimeters

All users issued with personal dosimeters must follow these requirements:

- Wear the assigned dosimeter(s) whenever working with radiation or radioactive substances at the locations specified on the RUA;
- Wear personal dosimeters correctly (see Figure 4):
- Whole-body badges must be worn on the waist or at chest level. It is important that the badge is worn with the sensitive area facing out (rather than facing the body). The badge must not be covered while it is being worn (e.g. it must be worn on the outside of the user's lab coats);
- Extremity monitors (rings) are usually worn on a finger of the hand most used, with the active area facing the radiation source (i.e. dosimeter sensitive area on the palm side of the hand). The extremity dosimeters must be worn under gloves to prevent them from being contaminated when working with unsealed radioactive substances;
- Store personal dosimeters away from sources of radiation and extreme environment (e.g. extreme moisture or extreme heat);
- Exchange and return personal dosimeters as soon as possible after the replacements arrive. If a replacement dosimeter fails to reach you on time, inform the RSO at hse@kaust.edu.sa, but keep using the original dosimeter until you have obtained a replacement;

- Contact the RSO, LSR or RLCL management as well as the RUA holder promptly if you lose a personal dosimeter. The RSO will provide a replacement dosimeter and work with you to assess and document the radiation dose for the period covered by the lost dosimeter;
- Use only the personal dosimeter that was provided to you. Never borrow a dosimeter assigned to anyone else and never loan anyone a dosimeter;
- Never intentionally expose your personal dosimeter to sources of ionizing radiation;
- Promptly notify the RSO, LSR or RLCL management as well as the RUA holder if you accidentally expose your personal dosimeter.

Figure 8.1. Personal dosimetry badge position

9.7. Monitoring results and notifications

All exposure monitoring results are reviewed by the RSO to ensure that regulatory dose limits (also called primary dose limits) and accepted dose constraint levels are not exceeded and that exposures are consistent with the ALARA principles. Any occupational exposures greater than the KAUST dose constraint levels require investigation.

For general public exposure, any exposure greater than the NRRC public dose levels also require investigation.

If an individual's radiation exposure exceeds the accepted levels, he/she as well as the RUA holder must be notified in writing of the nature and extent of their exposure. In addition, all personal monitoring results are kept by HSE for 30 years or until the person reaches 75 years of age (whichever comes last) as requested by NRRC.

In the case of known or suspected overexposures, the RSO must notify the Competent Authority (NRRC). The RSO and IRSC may recommend the individual to undergo medical evaluation and/or treatment by a qualified physician.

At any time, personnel may request a summary report of the doses received while working on KAUST research spaces. To protect confidentiality, the request must be written and signed by the person asking for the report and submitted to the RSO for action.

10. Operating Procedures for Work with Radioactive Sources

10.1. Receipt of radioactive materials

The licensed carrier delivers all radionuclides' shipments to the RLCL or the designated radioactive material storage area in the radioactive waste bay. Upon delivery, the RSO and/or the delegated safety specialist inspects and receives the shipment according to *Reception of Radioactive Materials SOP*. When receiving a radioactive shipment, the RSO and/or the RLCL radioisotope safety specialist shall inspect each package for the following:

- Conformance with RUA activity level and KAUST limits;
- Inspect the package for damage;
- Perform contamination monitoring of the package and record the results.
- Fill out all necessary documentation (e.g., inventory, etc.);
- Assign a unique vial ID to each received radioactive material.
- Place the radioactive substances in the appropriate storage area.

Fig. 9.1 Receiving a radioactive shipment in the Core radiation laboratory

10.2. Security of radioactive materials

The RLCL management is responsible for security of the radioactive substances kept in the RLCL (see section 5.4). The RSO is responsible for radioactive sources kept in the designated radioactive waste storage building. Under special conditions, some RUA holders are permitted to use Uranyl Acetate or Uranyl Nitrate (Appendix 5) for staining slides in electron microscopy within their laboratory's premises. The corresponding RUA holder is responsible to keep the stock of the uranyl compounds locked away and secured in their laboratory. RUA holders must ensure work environments are established for the safe use of the Uranium materials as specified in the respective RUA and following the safety information of Appendix 5.

Access to the area where stand-alone sealed sources or unsealed radioactive substances are present must be restricted (e.g. door lock or proximity access) to prevent unauthorized use or removal of radioactive substances. Examples of methods of securing unattended radioactive sources include locking/restricting entry to the laboratory and locking the refrigerators or cabinets where radioactive sources are stored when they are not in use. If non-authorized users are permitted in the laboratory, they must be under the supervision of an authorized user at all times.

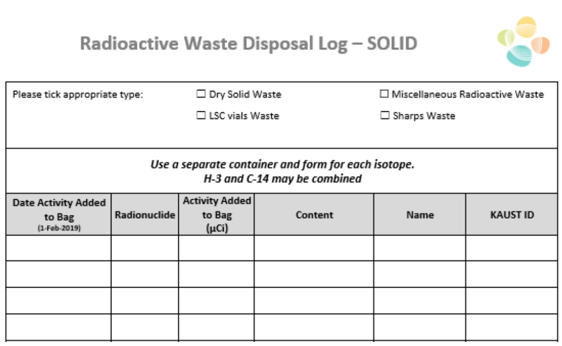
Any loss or potential loss of radioactive substances must be reported to the RSO as soon as possible after the loss is suspected.

10.3. Labeling requirements when working with unsealed radioactive substances.

Labeling containers

All containers containing radioactive substances must be labelled appropriately. The label must be clearly visible and include the following information: Vial ID, radionuclide, activity, reference batch number or reference date, other hazardous chemical used. The containers that must be labeled include:

- Vials and glassware (liquid scintillation vials are exempt from this requirement);
- When double containers are used, both inner and outer containers must be labeled (unless the inner label is visible from the exterior);
- Radioactive waste bins kept on the benches during an experiment. The radionuclide and the approximate amount of radioactivity accumulated in the radioactive waste container must be posted. Figure 9.2 is an example of a solid radioactive waste accumulation log that must be posted on each radioactive waste container.



Radioactive Waste Disposal Log – SOLID

Please tick appropriate type: ☐ Dry Solid Waste ☐ Miscellaneous Radioactive Waste ☐ LSC vials Waste ☐ Sharps Waste

Use a separate container and form for each isotope.
H-3 and C-14 may be combined

Date Activity Added to Bag (1-Feb-2019)	Radionuclide	Activity Added to Bag (µCi)	Content	Name	KAUST ID

Figure 9.2. Example of a radioactive waste accumulation log for solid waste.

Labeling Equipment

Equipment used that may be potentially contaminated must be labeled with trefoil sign or "Radioactive Material" caution tape (Figure 9.3).

In addition, cupboards and refrigerators used for storage of radioactive substances must be labelled with a trefoil sign. The label could also include the isotopes and maximum quantities allowed.

Figure 9.3. Labelling of all potentially contaminated equipment.

Labeling Work Areas

All work areas used for work with radioactive substances must be labeled. "Radioactive Material" caution tape should be used to clearly delineate the area(s) where work with radioactive substances takes place, including secondary protection trays. At least one bench or area label must identify the radionuclide(s) being used in that area and must contain a radiation symbol (trefoil).

Requirement for Removal of Labeling from Equipment

Prior to sending equipment previously used in research involving the use of radioactive sources for repair or disposal, RUA holder should ensure the following actions are taken and the RSO has been notified:

- Survey the equipment appropriately and confirm that they are free of contamination;
- Maintain records of any surveys performed to release the equipment for repair or disposal;
- Remove or obliterate all radiation labels and postings.

10.4. Spill Kit

Spill kits should be available in areas where unsealed radioactive substances are present. This kit must contain all the essential tools to help cleaning personal or area contamination.

The spill kit must be placed in an easily accessible location and clearly indicated so it can be easily found. Items that should be included in a spill kit are detailed in Appendix 3.

The content of the spill kit must be checked periodically to ensure that nothing is missing, or equipment is out of calibration.

10.5. Best working practices

The following are general procedures to control radiation exposure in areas where radioactive materials are present:

- Restrict access to members of the public and unauthorized users;
- Place warning signs at the entrances to the area;
- Do not bring personal belongings, other than those required for work, inside the area;
- Separate radiation work and storage areas from general personnel spaces. Store your lab coat and PPE at the entrance of the area;
- Do not eat, drink, smoke, or apply cosmetics in the area where unsealed radioactive substances are present;
- Maintain good housekeeping in the area;
- Wear impervious gloves and use tongs;
- Use a spill tray when working with large volumes of liquids or cover the work areas with absorbent paper. Note that the absorbent paper must be replaced regularly;
- Use the appropriate shielding for the isotopes used (Appendix 2);
- Put waste materials in appropriate containers and keep liquid waste in secondary containers;
- Use mechanical (remote) pipetting techniques;
- Use fume hoods when working with volatile materials;
- Wear appropriate PPE over street clothes (e.g., fire resistant clothing if working with flammable materials).
- Label work areas, equipment, and containers (including waste bins) as required;
- Clearly label contaminated glassware or equipment until it has been decontaminated;
- Perform radiation survey of the areas (e.g., survey meter or area “wipe test”), at the frequency specified in the Local Rules or by RSO and record the results.
- Use the appropriate radiation-detection equipment during handling of unsealed radioactive substances to detect and prevent the spread of contamination.
- Check gloves, forearms, and other PPE for contamination frequently;
- If contamination is suspected in the course of work, monitor the area using a suitable survey meter or area wipe, decontaminate if necessary and record the results;

– Wash your hands, check them with a suitable survey meter before leaving the laboratory, and record the results.

10.6. Contamination monitoring

Contamination is most easily detected by conducting routine monitoring surveys to detect excessive radiation and/or contamination levels. This alerts the personnel of the potential hazards. Table 5 lists the various instruments recommended for detection of the radioactive substances currently used at KAUST.

Table 9.1. Recommended radiation detection devices.

Radiation Type	Isotopes	Energies	Detector
Alpha	-	All	Wipe - LSC
Beta	H-3	60 keV	Wipe - LSC
	C-14, Cl-36, P-32, P-33, S-35	60 keV	Wipe - LSC Pancake GM Counter
Gamma or X-ray	-	200 keV	Thin NaI(Tl) crystal scintillation Calibrated GM counter
	Na-22	200 keV	Thick NaI(Tl) crystal scintillation

Routine monitoring should occur during and following all active work with/handling of unsealed radioactive substances. Additionally, self-surveys of work areas shall be documented at least once a month or more frequently depending on the nature of the work. If more frequent documented self-surveys are required, it will be noted in the Local Rules.

Keep permanent written records of all area contamination survey results, including negative results. The survey records must include:

– Location, date, and radiation detection instruments used (model and serial number);
– Name of the person conducting the survey;
– Map of the surveyed area, with identifying relevant features such as active use, storage and waste areas;
– Measured exposure rates and/or contamination levels, keyed to location on a map of the area;
– Corrective action taken, if contamination or excessive exposure rates were found, and the reduced levels after corrective action(s).

For more information please refer to *the Contamination monitoring procedure*.

10.7. Decontamination requirements

Laboratory surfaces, equipment, and clothing may become contaminated in spite of proper precautions. Such contamination does not necessarily present a serious hazard, especially if it is (1) detected promptly, (2) not allowed to spread or be ingested, and (3) removed, to prevent cross-contamination to other surfaces and objects.

The RUA holder or RLCL management for the area is responsible for overseeing that decontamination is carried out properly and that personnel are instructed in decontamination procedures. The RSO provides assistance or supervision in cases of personal contamination or significant levels of contamination. During decontamination procedure the person must:

- Wear appropriate protective clothing (gloves, lab coats, etc.);
- Confine the spread of contamination, starting from areas of low contamination and working toward areas of higher contamination;
- When cleaning a work surface with a decontamination solution, always clean from the outside of the contaminated area working inward towards the center. Use a fresh paper towel with each pass and don't wipe the area in a circular fashion;
- Carefully remove all loose or easily removable contamination, then wash with soap, detergent, or special solvents;
- Place all soiled cleaning materials (e.g., absorbent materials, gloves, etc.) in a labeled radioactive waste container.

For more detailed information please refer to the Decontamination procedures.

Materials (glassware, pipettes, etc.) and equipment exposed to unsealed radioactive substances must be thoroughly decontaminated and properly surveyed to confirm the absence of residual radioactive substances before it can be re-used. Suitable survey equipment and techniques must be used and the results must be documented. For example, glassware and other contaminated equipment must be cleaned using laboratory detergents, acids, or cleaning solutions as appropriate. Contaminated equipment (e.g. pipettors, centrifuge rotors, etc.) can be soaked in a decontamination solution overnight to improve removability of contamination. All equipment/materials contaminated with long-lived radioactive substances and that cannot be cleaned to acceptable levels, must be disposed of as radioactive waste. Equipment contaminated with short-lived radioactive substances must be clearly identified and stored in a secure location to allow for radioactive decay.

Contact the RSO at hse@kaust.edu.sa for questions related to disposal of radioactive substances or questions regarding decontamination procedures.

10.8. Sealed Sources

Sealed sources can be contained inside analytical equipment such as Liquid Scintillation Counter (LSC) and Gas Chromatograph or can be stand-alone such as liquid scintillation standard sources or calibration check sources. A physical inventory of all sealed sources is required to be completed and documented.

Safety requirements

The following safety requirements should apply:

- For equipment containing sealed sources, the area is a Non-Designated Area; no warning sign need to be displayed at the entrances, but the equipment needs to have a radiation trefoil sign. In addition, the entry does not need to be restricted but only authorized users are allowed to use the equipment containing the sealed source;
- Area designation for the use of stand-alone sealed sources will need to be discussed with the RSO;
- The RUA holder must ensure that a record of training and authorization to use the stand-alone sealed source or equipment containing sealed source is available. All authorized users must adhere to the manufacturer instructions, safety requirements, Local Rules, and SOP;
- The RSO must be notified of any changes of location, modification of the device or safety features.

Labeling Sealed Sources

Sealed source shields, and/or the apparatus in which the source is mounted must be labeled with a permanent radiation warning sign. Unless otherwise indicated, the sealed source should also be labeled with the radioisotope, initial activity, and the date of initial activity.

Disposal of sealed sources

Removal or replacement of sealed sources installed in a device can only be done by individuals authorized by the manufacturer or approved contractors. Sealed sources that need to be disposed of must be returned to the manufacturer or manufacturing country. However, before the source can be sent back, the RUA holder must notify the RSO. Please refer to *the Management of Disused Sealed Sources Guideline*.

For transfer of sealed sources outside of KAUST research spaces (either disposal or transfer of ownership) the following requirements must be met:

- Prior approval from the RSO and receiving person/company;
- Packaging, monitoring and labeling must be performed or inspected by the RSO;
- Copies of all transfer and shipment paperwork must be forwarded to the RSO;
- A copy of the recipient institution’s radioactive substances license must be on file prior to shipment.

Leak test

Sealed sources must be leak tested every six months except sealed sources incorporated inside Liquid Scintillation Counters. The RSO performs these tests and advises the RUA holder/responsible person of the results and any actions that must be taken.

11. Radiation Producing Equipment

This program is designed to guarantee that the use of X-ray producing devices at KAUST adheres to all applicable NRRC and university guidelines.

At KAUST a variety of radiation-producing equipment are used such as:

- Scanning and Transmission electron microscopes (SEM/TEM) and similar equipment used for materials research
- X-ray diffraction equipment (XRD)
- A high-voltage x-ray irradiator
- Cabinet X-ray systems
- X-ray fluorescence analyzers (portable XRF and bench-top XRF)
- X-ray photoelectron spectrometers (XPS)

Most equipment that uses radiation and operates above **5 kV** needs to be registered with the NRRC. To ensure compliance, consult with the RSO before acquiring such equipment.

HSE will provide the following services for users of radiation-producing equipment:

- Registration (HSE will handle all the paperwork to register radiation-producing equipment or to cancel registrations)
- Training
- Radiation Surveys
- Radiation Monitoring Badges

Important Reminders

- The NRRC regulations and the university's IRSC policy require new radiation-producing equipment to be registered and approved before operation. Any radiation-producing equipment will be suspended by the RSO if it is operating without prior approval from the IRSC.
- The NRRC regulations and the university's IRSC policies also require radiation-producing equipment that has been moved or repaired to be inspected before being returned to service.
- Lastly, depending on the type of equipment, the university's IRSC policies require that all users of radiation-producing equipment complete the HSE Analysis X-ray Safety Training or SEM/TEM Safety Training before the first use of the equipment.

11.1. Personal Protective Equipment

No additional, Personal Protective Equipment (PPE) such as PPE containing lead or lead equivalent material is required but all general laboratory PPE must be worn when entering the laboratory space. If additional PPE is required the RSO must provide advice and this will be indicated in the Local Rules.

11.2. Radiation Survey

The RSO is required to conduct area-monitoring surveys of the radiation-producing equipment on the KAUST research spaces as follows:

- Annually, as part of routine tests to check for radiation leakage;
- Following any installation, major changes in configuration, maintenance or repair.

11.3. Safety Devices

Radiation-producing equipment must be equipped with certain safety features. These typically include a fail-safe warning light, fail-safe interlocks, beam enclosures, and shielding. In addition, a radiation survey meter may be needed.

The following procedures apply to all radiation-producing equipment:

- Safety devices must be in working order before the machine is operated;
- Only repair persons authorized by the manufacturer (e.g. manufacturer employee or sub-contractor) may operate a radiation-producing equipment without using shielding and other safety devices;
- Any changes to the safety devices must be reviewed by the RSO. Do not replace or modify safety devices without pre-approval;
- No safety device is absolutely fail-safe or foolproof. Interlocks, like those on the door of a cabinet X-ray unit must not be relied on to automatically close the beam shutter;
- Safety devices must not be purposely defeated, even when their use makes operating the machine difficult. If the design of a safety device prevents or inhibits operation, the RSO may approve an alternate safety device or method of equal protective value. (If safety devices are modified, it may be necessary to modify existing operating procedures or the RUA, and to retrain operators);
- Do not operate a machine if a required safety device fails. Do not use the unit until it has been repaired and checked by the RSO.

11.4. Users Log

It is required that a "Users log" is maintained for each radiation-producing equipment (see radiation safety webpage). This log can be helpful when investigating incidents and/or to look at the machine operating status. The "Users log" must include the following:

- Date;
- User's name;
- Beam voltage and beam current;
- Start and end time;
- Any comments (e.g. faults in equipment, repairs, etc.).

11.5. Standard Operating Procedures, Local Rules and safety requirements

Standard Operating Procedures (SOP) and Local Rules for each radiation-producing equipment must be established by the RUA holder with RSO assistance if needed. The SOP must describe in details how the machine is used in practice (e.g. how to load a sample, how to select the image processing, etc.). In addition, Local Rules must be written and kept with the SOP, these describe all the safety measures that must be observed, dosimetry requirements, emergency procedures, etc. Each user of radiation-producing equipment is required to read the unit-specific SOP and the Local Rules.

A summary of the safety requirements for the various radiation-producing equipment is presented in the sections below:

11.6. Safety requirements for radiation-producing equipment

Administrative safety requirements

- The laboratory space is designated as a Supervised or Controlled Area. The designated area will need to have visible barriers and warning signs posted at the entrances;
- When a space is designated as Controlled Area only authorized staff, which have been trained, are allowed when the device is switched on. When a space is designated as Supervised Area entry restriction does not apply but only authorized users, which have been trained, are allowed to operate the radiation-producing equipment;
- For this equipment, the RUA holder must ensure that a record of training and authorization to use the device is available. All authorized users must also fill the authorized user form and return it to the RSO;
- All authorized users shall adhere to the manufacturer instructions, safety requirements, Local Rules and SOP, and complete the users log whenever they use the device;

- The authorized users must wear all dosimetry badges issued to them;
- The RSO is required to perform an annual area monitoring to ensure that the radiation doses to the users and other staff do not exceed the occupational dose limits and associated KAUST accepted dose levels;
- The RSO must be notified of any changes of location, modification of the device or safety features, etc.;
- The RSO must be notified immediately if any safety interlocks fail to operate as intended or if you suspect an accidental exposure.

Engineering safety measures

- The primary beam must be shielded such that (1) no radiation levels outside the enclosure exceed 1μSv/h, (2) no person can stand within the enclosure while the machine is producing X-rays, and (3) all shielded entrances of the equipment are interlocked so that any attempt to open the enclosure will shut off the machine. In addition, warning indicators should be available to indicate when the X-ray tube is energized, or if the shutter is open (i.e. primary X-ray beam entering the main chamber).
- It is good practice that the entrances to the laboratory containing radiation-producing equipment are controlled (i.e. via locks or proximity access).
- The entrances to the laboratory containing radiation-producing equipment must be controlled (i.e. via locks or proximity access);
- Entrance warning signs must be posted and warning indicators should be available on the equipment to indicate when the X-ray tube is energized, or if the shutter is open (i.e. primary X-ray beam entering the main chamber).

11.7. Remove radiation-producing equipment from use

When radiation-producing equipment are removed from use, the RSO must be notified. Examples of such notification include:

- Before a radiation-producing equipment is removed from KAUST research spaces (for disposal or resale), the RSO must be provided with the decommissioning documentations so the equipment can be removed from the inventory and NRRC national registries;
- If a radiation-producing equipment is deactivated or rendered incapable of producing radiation, the RSO must be informed and the device, which is deactivated but left on KAUST research spaces, must be labeled with the words: "**DO NOT USE - DEACTIVATED X-RAY EMITTING DEVICE**" and make the plug inoperable. Once a device has been deactivated, do not operate or reactivate it without notifying the RSO.

11.8. Disposal of radiation-producing equipment

The RSO must be notified when a radiation-producing equipment is disposed of or sold to another entity at least 30 days before the transfer of the equipment outside KAUST research spaces. In addition, the RSO must be provided with the decommissioning paperwork so the equipment can be taken off the inventory.

12. Radioactive Waste Management and Disposal

Radioactive waste generated through research involving the use of radionuclides is subject to strict the Saudi radioactive waste regulations developed by the Competent Authority NRRC.

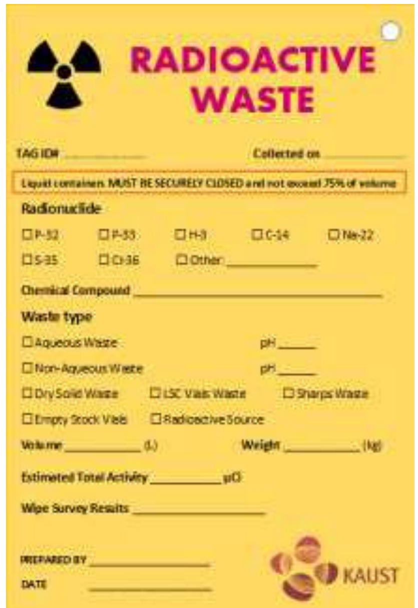
The RSO or staff authorized by the RSO are responsible for the collection, processing, and disposal of all forms of radioactive wastes generated on campus. Radiation workers must be aware that accounting of the radioactive waste is an important part of the radioactive substance inventory that is required by the Competent Authority. As a result, solid radioactive waste must not be placed in the regular waste containers and liquid radioactive wastes must not be disposed into the sewer system.

All radioactive waste must be carefully prepared in accordance with the procedures detailed below and ***the Radioactive Waste Preparation SOP***.

12.1. General requirements

The following requirements must be adopted by all individuals working in the areas with unsealed sources:

- For each experiment the radiation user must maintain accurate records of the type, quantities, and form (solid, liquid, etc.) of radioactive waste generated. In addition, precise records of the stock, usage and waste generated for each radionuclide must be kept;
- During an experiment, the radiation worker must ensure that radioactive waste containers are kept near to minimize the possibility of spillage;
- A log of the waste containing (Name, KAUST ID, date, isotope, volume, reference date or vial ID, and activity) must be kept on every radioactive waste container;
- All radioactive waste containers must be labeled with the radioactive trefoil sign as well as the indication “Caution Radioactive Substances”;
- Once sealed, the radioactive waste container must be labeled with a Radioactive Waste Tag (Figure 10.1) and the log sheet is attached to it from outside.
- Radioactive waste containers must be kept closed except when adding waste. Liquid waste containers must be kept in secondary containment at all times;
- P-32 waste should be shielded with at least 1cm or 0.4-inch plastic; while Na-22 waste must be shielded using lead or lead equivalent materials. For any questions on thickness requirement, please contact the RSO;
- When radiation workers are handling and preparing radioactive waste they must wear the appropriate PPE such as a lab coat, disposable gloves, safety eyewear, closed-toes shoes and the dosimetry badges issued to them;
- <u>Do not correct for decay</u> once radioactive items have been disposed as radioactive waste. Simply indicate in the waste log the isotope, the activity at the time of the experiment and reference date or the vial ID.


RADIOACTIVE WASTE

TAG ID# ________ Collected on ________

Liquid containers MUST BE SECURELY CLOSED and not exceed 75% of volume

Radionuclide

☐ P-32 ☐ P-33 ☐ H-3 ☐ C-14 ☐ Na-22

☐ S-35 ☐ Cl-36 ☐ Other: ________

Chemical Compound ________

Waste type

☐ Aqueous Waste pH ____

☐ Non-Aqueous Waste pH ____

☐ Dry Solid Waste ☐ LSC Vials Waste ☐ Sharps Waste

☐ Empty Stock Vials ☐ Radioactive Source

Volume ________ (L) Weight ________ (kg)

Estimated Total Activity ________ µCi

Wipe Survey Results ________

PREPARED BY ________

DATE ________

KAUST

Figure 11.1. Example of a radioactive waste tag.

12.2. Waste minimization

Each user must follow procedures that reduce the amount of radioactive waste generated. Waste minimization methods include:

- Order only the minimum amount of radioactive substances required for the experiment;
- Whenever possible use short-lived radionuclides (i.e., with half-lives less than 90 days) rather than long-lived radionuclides;
- All radioactive waste must be segregated by radionuclides (i.e., one waste container per radionuclide);
- Any items (e.g., gloves, paper, etc.) that have been in direct contact with radioactive substances (i.e., used as part of an experiment involving radioactive substances) must be considered contaminated and be placed in the solid radioactive waste container. Other items that have not been used to handle radioactive substances must be checked for detectable contamination prior to disposal as ordinary waste. If contamination is detected the items must be managed as radioactive waste;
- Normal Regular waste bins must be monitored to ensure that they are free of removable contamination before being picked-up by KAUST Site Services;

- Restrict work to surfaces that can be easily decontaminated (e.g., use tray or absorbent paper) to minimize the amount of waste generated from a spill;
- Use “biosafe” liquid scintillation cocktails (see list in section 10.5). Samples with counts of less than 3 times background level or wipes with less than 4 Bq/cm2 or 240 dpm/cm2 are considered non-radioactive;
- Flammable solvents such as liquid scintillation cocktails containing xylene or toluene must not be used without prior approval from the RSO;
- Use plastic liquid scintillation vials instead of glass, whenever practical;
- Whenever possible, use methods that do not involve radioactive substances;
- Empty shipping packages (excluding stock vials) used for shipping radioactive substances that are free from contamination can be disposed in regular waste containers. Before being disposed in regular waste containers all radioactive markings and labels must be completely removed or obliterated.

12.3. Solid radioactive waste

Definition

Solid non-sharp radioactive waste consists of:

- **Dry Solid Waste**
  - Dry radioactively contaminated items which includes but is not limited to paper, paper towels, gloves, bench paper, empty stock vials, disposable pipette tips, etc. Small amount of damp material may be present, but solid waste must not contain free liquids (free liquid means an amount of liquid waste which can easily run and thus could easily be spilled before disposal as a solid radioactive waste).
- **Miscellaneous Radioactive Waste**
  - Metallic lead, sealed radioactive sources, smoke detectors, sources that emit alpha radiation (such as uranyl acetate or thorium compounds), or containers with freestanding liquids are not considered as dry radioactive waste.

Packing Instructions

- All solid radioactive waste must be segregated by radionuclides;
- Solid radioactive waste must be double bagged using two clear 3 mils thick plastic bags (Figure 8). Biohazard bags must not be used;
- Solid waste bags must be labeled with the radionuclide and radiation trefoil sign. The waste log sheet should also accompany the bag and be attached to the outside;
- Radioactive waste containing radionuclides with a half-life less than 90 days (e.g. P 32, P-33 and S-35) will be transferred to the dedicated waste building and decayed in storage for at least 10 half-life or until the activity of the waste is

indistinguishable from background or measures less than two times the average background value, and then disposed as regular waste after the approval of the NRRC. As a result, all markings and symbols must be removed or obliterated by the authorized users prior to being placed in a waste container;

- Radioactive waste containing long-lived radionuclides (i.e. with a half-life of more than 90 days such as Na-22, H-3, C-14, and Cl-36) will be transferred to the dedicated waste building for storage;
- When the bag is sealed, the external surface of the closed bag must be free of removable contamination (i.e. less than two times background level). Wipe survey results must accompany each waste bag placed for removal;
- Surveyed bag with negative results must be tagged with a completed Radioactive Waste Tag and placed in the accumulation area in the RLCL storage room while awaiting removal.

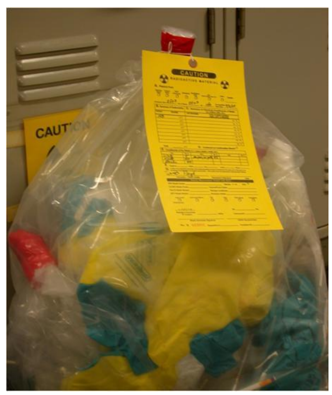


Figure 11.2. Example of packing for solid waste ready for pick-up.

12.4. Aqueous liquid radioactive waste

Definition

Liquid waste includes water and water soluble liquids. Although small amounts of non-soluble materials may be present, liquid waste should generally not contain solid materials or non-water soluble liquids. Disposal of radioactive liquid waste via sink is not permitted; only tertiary, or higher, aqueous washes may be poured in the designated lab sink (i.e. disposed of in the sewer system) and recorded on the Radioactive Sink Disposal log.

Packing instructions

- All liquid waste must be segregated by radionuclides;

- Liquid waste must be disposed of in a carboy. The carboy must not be filled past the fill mark or to about 75% of its full content. Overfilled carboys are a transport hazard and will not be picked up;
- Carboys must be placed in secondary containers;
- Carboys containing liquid radioactive waste must be labeled with the radionuclide, the chemical constituent and radiation trefoil sign on two opposite sides. The waste log sheet must also accompany the container;
- The measurement of the aqueous liquid radioactive wastes pH should be performed before tight sealing the carboys using paper pH strips, the pH level must be between 6 and 10.
- When the carboy is full, it can be sealed, and the external surface of the carboy must be free of removable contamination (i.e. less than 2 times background level). Wipe survey results must accompany each waste carboy placed for removal;
- Surveyed carboys with negative results must be tagged with a completed Radioactive Waste Tag and placed in the accumulation area (the RLCL storage room or inside the designated fume hood for uranyl acetate waste) while awaiting removal;
- Liquid waste containing radionuclides with a half-life less than 90 days (e.g. P 32, P-33 and S-35) will be transferred to the dedicated waste building and decayed in storage for at least 10 half-life or until the activity of the waste is indistinguishable from background or measures less than two times the average background value, and then disposed as regular waste after the approval of the NRRC. As a result, all markings and symbols must be removed or obliterated by the authorized users prior to being placed in a waste container
- Carboys still in good condition will be returned to the lab after the decay period;
- Small volumes of high activity liquid (e.g. stock solution) must not be placed into liquid waste containers. Such liquid waste must be capped and stored separately for collection by the RSO or staff authorized by the RSO.

Figure 11.3. Example of a liquid waste container ready for pick-up

12.5. Liquid scintillation vials

Definition

Liquid scintillation vials waste consists of all the vials containing radioactive compound mixed with liquid scintillation cocktail. Liquid scintillation vials must not contain metallic compound such as lead, etc. Only “biosafe” liquid scintillation cocktails can be used. Contaminated liquid scintillation cocktail waste must be kept separate from other wastes and disposed as radioactive waste.

The list of all KAUST approved liquid scintillation cocktails is shown below. Please note that this list is non-exhaustive and new “biosafe” liquid scintillation cocktails can be added upon approval from the RSO:

Manufacturer	Product Name	Manufacturer	Product Name
Amersham	NBCS 204	ICN	UniverSol ES
Atlantic Nuclear	Eco-Safe	ICN	BetaMax ES
Beckman	Ready Safe	ICN	CytoScint ES
DuPont	NEF-989	Isolab Inc	Solvent Free
Fisher	Scint-safe Econo 1	National Diagnostics	Ecoscint
Fisher	Scint-safe Econo 2	Perkins Elmer	Ultima Gold
Fisher	Ultima-Flo AP	Perkins Elmer	Opti-Flour
ICN	Ecolume		

Any scintillation cocktail not on this list must receive prior approval from the RSO. To obtain approval for other scintillation cocktails please contact *hse@kaust.edu.sa*.

Packing

- Scintillation vials that do not contain radioactive material are disposed of as regular hazardous waste, not radioactive waste.
- Do not empty LSC vials into any other containers, all scintillation vials must be packaged in their original tray/box.
- If the original trays are not available, or if mini vials are used, the waste vials must be double bagged in the 4 mil transparent plastic waste bags, and marked with "Caution Radioactive Materials" and trefoil radioactive symbol.
- Use a secondary container labelled with the radiation trefoil sign on at least 2 sides and indicating “LSC Plastic Vials Waste”.
- Tightly cap each vial.
- When the box/bag is full, attach a radioactive waste tag. Add, total activity and the name of Scintillation Cocktail.

– Notify the RSO for collection.

Figure 10. Example of liquid scintillation vial original box.

12.6. Mixed radioactive waste

Mixed waste is defined as waste that is classified as radioactive and contains chemicals that are listed as hazardous. This may include chemicals that can ignite, corrode, react, flammable, or toxic.

At present KAUST does not permit the use of hazardous chemicals with radionuclides. Prior approval from RSO and IRSC is required to produce such waste as it is extremely difficult to treat and dispose.

12.7. Sharps and glassware

Definition

Sharp and glassware waste include any material that is solid and non-combustible such as razor blades, hypodermic needles, scalpels, broken glass, glass scintillation vials as well as all other glassware, etc.

Packing

– All sharp waste must be placed in a puncture resistant sharp container;
– All sharp waste must be segregated by radionuclides;
– Containers must be labeled with the radionuclide and radiation trefoil sign on two opposite sides. The waste log sheet should also accompany the container;

- If the sharps radioactive waste also contains biohazards, the biohazard sign must be placed on the container along with the radioactive label;
- When the container is full, it can be sealed and the external surface of the bag and/or container must be free of removable contamination.
- Surveyed waste containers with negative results must be tagged with a completed Radioactive Waste Tag and placed in the accumulation area in the RLCL storage room while awaiting removal.

12.8. Lead

Definition

Lead containers are often used as source vial enclosures to provide shielding. Lead container and other lead items must not be disposed with regular waste.

Packing

- Lead waste items and containers must be surveyed to ensure they are free of removable contamination (i.e. less than 240 dpm per cm2 or less than two times background level);
- Any markings or labels indicating the presence of radioactivity must be removed or defaced prior to disposal.
- Lead pigs must be collected for recycling separately from all other radioactive waste types and may not be placed in dry solid waste containers. Please contact the RSO for additional guidance on lead pigs.

12.9. Stock Vials (source vials)

- Separate the source vials by isotope.
- Always deface any radioactive labels on stock vials placed into decay storage boxes.
- Never place stock vial contents into liquid waste containers, this will increase the total activity of the container and make it difficult to dispose of.
- Place source vials in plastic bags. You are not required to empty the source vials prior to pick-up for disposal. You do not need to account for radioactive decay. For the "empty" vials, record a value of 1% of the total original source vial activity. Example: for a vial originally containing 1 mCi of any isotope, 1 mCi x 0.01 mCi, record 0.01 mCi on the waste pick-up form and tag. For partially full vials, enter the value from the usage log. For unused vials, record the total vial quantity.
- Empty vials must have the label and markings obliterated and must be removed from shielding. Dispose of empty vials in the radioactive dry waste.

- Complete the Radioactive Waste Accumulation Log, as this can be disposed as source vials. In the activity section of the log enter the activity remaining in the vial on the day of disposal.

12.10. Packaging

Any packaging used for the transport of radioactive substances should be checked for contamination prior to being disposed and record kept. If the packaging is free from contamination, it can be disposed in the normal bin. If the package is contaminated it must be disposed in the solid radioactive waste bin.

12.11. Waste pick-up

Radioactive waste removal from the RLCL or labs using uranyl compounds should take place at regular time intervals to avoid the accumulation of radioactive waste. The lab safety person or radiation worker must fill out the radioactive waste pick-up form and submit it along with the radioactive waste pick-up request on the SALUTE system, to the RSO to arrange for radioactive waste pick-up. Waste that is not prepared in accordance with the outlined instructions will not be removed until it is adequately prepared.

13. Emergency Plans

In the event of an emergency (fire, explosion, chemical exposure, toxic gases, etc.) that is accompanied by the presence of ionizing radiation, it is important to first address hazards that have the greatest potential impact. Fire and life-threatening situations take precedence over radiation issues.

The quantities and types of ionizing radiation used at KAUST are low enough that professional attending fire and life-threatening incidents can carry out their work even if radioactive substances and/or radiation is present in the surrounding. Nonetheless, they must use personal protective equipment (PPE) and before leaving the scene (or at frequent interval), they must be monitored for radioactive substances contamination. If contamination is found, they must undergo the appropriate decontamination procedures.

The RSO must be notified immediately of any of the following situations:

- Body contamination;
- Ingestion of radioactive substances;
- Unexpected external personal exposure to ionizing radiation;
- Severe contamination of equipment, tools and areas;
- Major spills and/or spread of contamination;
- Unplanned release of radioactive substances;
- Difficulty cleaning up a contaminated area;
- Loss or theft of radioactive substances or radiation-producing equipment.

The RSO contact details must be available on the laboratories Local Rules which must be kept next to the equipment or in the laboratories.

13.1. Communication and Notification

Information notices must be posted at places where foreseeable accidents may occur. They must include:

- The contact details of the RSO as well as an alternative person within the Research Safety Team (RST) that needs to be notified immediately in case of an emergency. The RSO/RST will then contact NRRC;
- The contact details of Lab safety specialist/ lab manager
- KAUST emergency phone numbers

13.2. Personnel Contamination

In the case of life-threatening personnel contamination, immediately call or have someone call 911 from a campus phone or 012 808 0911 from a mobile phone and explain the situation. Then notify the RSO.

If the personal contamination is not life-threatening immediately contact the RSO and during off hours, call 054 038 3173 to reach the HSE on-call phone and ask for radiation safety assistance.

The objective of personal decontamination is to minimize the dose to the skin as well as internal dose. Decontamination techniques aim to remove or reduce the externally and/or internally deposited contamination.

In the case of a radiation accident, follow these steps:

1. Treat medical problems first and administer first aid as appropriate. Ask others in the area to assist. First aid and prompt medical treatment take precedence over decontamination. Usually, decontamination can wait until the victim is in stable condition;
2. Immediately remove contaminated clothing and flush skin with water;
3. For skin contamination, follow these decontamination procedures:
    a. Wash the contaminated area using a mild soap and lukewarm water. Do not use hot water or break/rub the skin. Do not use brushes that could damage the skin;
    b. If the contamination is widespread, a shower with mild soap and lukewarm water will usually remove most of the contamination. After the shower, survey the person to determine the effectiveness of the decontamination and to localize any remaining contamination;
    c. The RSO may recommend additional or specialized decontamination efforts if further decontamination is needed;
4. Bag all contaminated clothing and materials. The RSO can provide details on decontamination or disposal.

For more details on decontamination procedures please refer to the Personal Decontamination Procedures.

13.3. Minor Spill

A minor spill in an incident that involves all of the following criteria:

- Less than 370 kBq (or 10 µCi) of radioactivity has been spilled;
- The contamination is limited to a small area (approximately 50×50 cm);
- There is no clothing or skin contamination;
- You are certain that you can manage the surveys and decontamination procedures on your own without assistance.

In case of a minor spill follow these steps:

1. Notify all persons in the area that a spill has occurred;
2. Allow only necessary personnel to enter the area;
3. Put on personal protective equipment (PPE) as necessary;
4. Prevent the spread of contamination by covering the spill with absorbent paper (if solids are spilled, paper should be dampened). Use absorbent paper as needed to clean up the spill;
5. Perform frequent surveys with an appropriate survey meter to determine the effectiveness of the decontamination process;
6. During and after the cleanup procedure, carefully place the absorbent paper in a double plastic bag tagged and labeled with contents, radioisotope, and date. Put contaminated gloves and any other contaminated disposable materials in the bag;
7. Survey the area with a meter or other appropriate technique. Check the area around the spill for residual (sometimes called “fixed”) contamination;
8. Survey all persons involved in the decontamination process; check hands, clothing, and shoes for contamination. Once personnel have been surveyed and found free of contamination, record their names and release them. If personal contamination is detected, follow the procedure described above under “Personnel Contamination”;
9. Do not allow work to resume in the area until approved by the RSO or the lab management personnel that have been delegated authorization from the RSO.

13.4. Major Spill

A major spill is any incident that is not a minor spill and includes the discovery of contamination in unexpected places or in many places.

In this case, alert everyone not involved in the spill to leave the area immediately but assemble nearby. Call or have someone call the RSO or 911 from a campus phone or 012 808 0911 from a mobile phone and explain the situation. During off hours, call the HSE on-call phone 054 038 3173 and ask for radiation safety assistance.

1. The RSO or individual authorized by the RSO must perform a radiation survey assessment of all individuals who could possibly have been contaminated;
2. Once potentially contaminated persons have been surveyed and found free of contamination, record their names and release them. When feasible, use reasonable effort to confine contamination;
3. Prevent inadvertent entry or re-entry into the contaminated area. Post all entrances to the room or area with sign(s) warning others that a spill of radioactive substances has occurred. Post similar signs in the general vicinity, indicating the location of the spill;

4. Wait for the RSO directions before taking further action. Follow the instructions of the RSO regarding decontamination techniques, surveys, provision of bioassay samples, requested documentations, etc.;
5. Do not allow work to resume in the area until approved by the RSO;
6. Place contaminated clothing and materials in tagged bags labeled with contents, radioisotope, and date.

13.5. Theft/Loss of source

If you suspect or have confirmed loss of radioactive source(s) and/or radiation-producing equipment, you must notify the RSO or Research Safety Team promptly and request special instructions regarding securing the area. You will also be required to cooperate with the RSO to investigate of the cause of the loss of the source(s).

The RSO will then be responsible for:

1. Informing senior management
2. Informing the Competent Authority (NRRC) immediately about the incident;
3. Assessing the situation, and if a threat is confirmed, notifying the KAUST Security Services, Executive Management;
4. Initiating an immediate and exhausting search for the source(s) in full cooperation with the KAUST security services and Competent Authority;
5. Documenting the incident investigation in progress.

Once the incident is eliminated, the RSO will have to determine the cause of the threat and needed corrective actions. File a final incident report to the Competent Authority and KAUST Executive Management indicating the cause(s) of the incident, assessing the necessary steps to prevent a recurrence and initiating corrective actions immediately.

13.6. Radiation-producing equipment Failure

1. TURN OFF MACHINE by pressing the red emergency stop button. If possible, de-energize circuit breakers;
2. Treat medical problems first and administer first aid as appropriate. Treatment of injuries takes precedence over radiation exposure;
3. If life threatening incident call 911 from a campus phone or 012 808 0911 from a mobile phone and explain the situation. Then notify the RSO, during off-hours call the HSE on-call phone 054 038 3173 and ask for radiation safety assistance;
4. Notify the RUA holder and others in the area;
5. Record all pertinent information about the incident, including operating voltage and current, exposure time, and distance from the radiation source. Provide this information to the RSO.

Note: Exposure to the primary beam of many X-ray machines can produce significant biological effects that are not immediately apparent. The RSO must be notified immediately and will initiate consultation with competent medical representative to assess the radiation dose and ensure proper medical follow-up.

14. Appendix 1. Glossary

Activity: The rate of disintegration (transformation) or decay of radioactive substances. The units of activity are the becquerel (Bq) and the curie (Ci).

ALARA (As Low As Reasonably Achievable): ALARA is a regulatory concept devised to ensure that every reasonable effort is made to keep exposures to radiation as far below the dose limits as is practical, consistent with the purpose for which the licensed activity is undertaken. ALARA takes into account the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations.

Ancillary Personnel: Individuals (such as maintenance workers, lab researchers, interns, students, administrative workers, etc.) who are not ordinarily exposed to radiation or radiation producing machines in the course of their jobs, but whose duties may extend to areas of potential exposure. and require basic radiation safety training. The RSO can provide an awareness training for these workers that is available on demand only.

Annual Limit on Intake (ALI): The derived limit for the amount of radioactive substances taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 20 mSv. (ALI values for intake by ingestion and by inhalation of selected radionuclides are given in Appendix 3).

Background Radiation: Radiation from cosmic sources, naturally occurring radioactive substances (including radon but 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 radioactive substances regulated by Competent Agency in the Kingdom of Saudi Arabia.

Becquerel (Bq): The SI unit of activity. One Becquerel (Bq) is equal to 1 disintegration (transformation) per second (dps or tps).

Supervised Area: A designated area in which the annual dose to the radiation worker is likely to exceed 3/10th of any applicable dose limits. In addition, in such area the external dose rate may exceed 3 µSv/h).

Designated Area: An area to which access is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to ionizing radiation. (See also **controlled area and supervised area**).

Dose: A generic term for any of the following: absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent (TEDE).

Dose Limits: The permissible upper boundaries of radiation doses established by, or in accordance with, the current regulations.

Dose rate: The dose per unit of time, such as Sievert per minute (Sv/min) and milli Sievert per hour (mSv/hr).

Dosimeter, Dosimetry: A device designed to be worn or carried for the purpose of measuring and registering an individual's radiation dose. Dosimeters include Thermoluminescent badges (TLD), Optically Stimulated Luminescence (OSL) badges, pocket dosimeters, and finger rings.

Electron Microscope: A device that visualizes matter via interaction with high-speed electrons. This includes both scanning and transmission units, regardless of accelerating voltage.

Engineering Controls: Safety features included as an integral part of a laboratory or other facility. Examples include increased ventilation, fume hoods, radiation shielding, and safety interlocks.

External Dose: Portion of the dose equivalent received from any source of ionizing radiation outside the body.

Extremity: Means a hand, elbow, arm below the elbow, foot, knee and leg below the knee.

Eye Dose Equivalent or Lens Dose Equivalent: The external dose equivalent to the lens of the eye at a tissue depth of 0.3 centimeter.

Fail-safe: A default protection design. If a fail-safe indicator or light fails, the operation it indicates will automatically cease. For example, if a fail-safe **"X-RAY ON"** light burns out, X-rays will automatically cease to be produced.

Gray (Gy): The SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule per kilogram (J/kg) (1 Gy = 100 rad).

Internal Dose: Portion of the dose equivalent received from radioactive substances taken into the body.

Investigation: The formal RSO Radiation Safety response to any radiological even - for example, in the event that an individual's combined external and internal exposure reaches the acceptable levels set in this manual.

Ionizing Radiation: (1) gamma rays and X-rays, and (2) alpha and beta particles, high-speed electrons, neutrons, protons, and other nuclear particles. (Sound or radio waves, or visible, infrared [IR] or ultraviolet [UV] light are **not** considered ionizing radiation).

IRSC: Institutional Radiation Safety Committee. A committee appointed by the Responsible Official and overseeing the use of ionizing radiation at KAUST.

NRRC: (King Abdullah City for Atomic and Renewable and Energy) Competent Authority responsible for regulating the purchase, use and disposal of ionizing radiation in the Kingdom of Saudi Arabia.

KAUST: All locations under the administrative control of the President of the King Abdullah University of Science and Technology (KAUST) campus.

Licensed Material: Source material received, possessed, used, transferred or disposed of under a general or specific license issued by NRRC.

Medical Machine: A device used to deliberately expose humans to ionizing radiation for the purpose of medical diagnosis or treatment. This classification is determined by use rather than design.

Member of the Public: An individual who is not exposed to ionizing radiation as part of his/her job.

Non-Occupational Dose: Dose received by an individual who does not work directly with ionizing radiation (e.g. office worker, maintenance person, building services person, visitor, etc.). See **Public Dose.**

Nuclear and Radiological Regulatory Commission (NRRC): The Competent Authority for Radiation Protection in Saudi Arabia.

Occupational Dose: Dose received by an individual in the course of assigned employment duties that involve exposure to ionizing radiation from licensed and unlicensed sources of radiation. This applies to both the licensee and others. Occupational dose does not apply to members of the public or to dose received from background radiation, medical administration, exposure to individuals administered radioactive substances, or voluntary participation in medical research programs.

Personal Monitoring: Means (1) the assessment of dose equivalent by the use of devices designed to be worn by an individual; (2) the assessment of committed effective dose equivalent by bioassay (see Bioassay) or by determination of the time-weighted air concentrations to which an individual has been exposed, i.e. DAC-hours; or (3) the assessment of dose equivalent by the use of survey data.

Personnel Monitoring Equipment: See Dosimetry.

Personal Protective Equipment (PPE): Safety equipment used by an individual for protection against expected or unexpected hazards associated with a procedure. Examples include gloves, goggles, shoe covers, and respirators.

Public Dose: The dose received by a member of the public from exposure to ionizing released by a licensee, or to any other source of radiation under the control of a licensee. Public dose does not include occupational dose or dose received from background radiation, medical administration, exposure to individuals administered radioactive substances, or voluntary participation in medical research programs.

Radiation-Producing Equipment: Any device capable of producing ionizing radiation when the associated control devices are operated. This does not include devices that produce radiation only by the use of radioactive substances.

Radiation Safety Officer (RSO): An individual who holds a license from the Competent Authority and has been delegated responsibility for the Radiation Safety Program.

Radiation Use Authorization (RUA): An authorization to use radiation, granted by the RSO and/or IRSC to an RUA holder.

Radiation Worker: An individual who is listed to work with ionizing radiation and has been properly trained.

RLCL Management (RLCL): Staff member assigned to oversee or manage operations of Radiation Labeling Core Lab.

RUA holder: An individual, usually a faculty member or person in charge, who has been authorized by the RSO or IRSC and granted a Radiation Use Authorization (RUA).

Radioactive Substance: Any material (solid, liquid or gaseous substance) that emits radiation spontaneously.

Radioisotope / Radionuclide: See radioactive substance.

Sealed Source: Any radioactive material encapsulated in such a way that it cannot be released under the severest conditions likely to be encountered during normal use.

Supervised Area: A designated area in which the annual dose to the radiation worker is likely to be between $1/10^{th}$ and $3/10^{th}$ of any applicable dose limits. In addition, in such area the external dose rate may be equal or above 1 µSv/h (but no more than 3 µSv/h).

Survey: An evaluation of the safety precautions put in place to protect against radiation hazards related to the production, use, release, disposal, or presence of radiation sources under a specific set of conditions. The evaluation often includes a physical inspection of the source of radiation and its surrounding area using suitable monitoring/sample-collection techniques. (See also **investigation.**)

Sievert (Sv): A special unit that expresses biological damage or risk from radiation.

Vial ID: Vial ID: A reliable unique number is manually assigned systemically to every radioactive stock vial received at RLCL to track the usage of the vial from date of receiving till it disposed finally.

X-ray Diffraction and Fluorescence Analysis Machine: A machine that produces X-ray beams to analyze various substances via X-ray diffraction or X-ray–stimulated fluorescence.

15. Appendix 2. Shielding requirement for various isotopes

The appropriate shielding requirement strongly depends on the emission characteristics of a particular isotope. The sections below summarize the safety precautions to be adopted when working with isotopes of similar emission type and energy. Contact the RSO at (hse@kaust.edu.sa) for any questions on proper shielding.

Low energy beta emitters

Table 14.1. Examples of low energy beta emitters.

Isotope	Half-life	Energy (E_{max}) in keV	Max. Range in Air (cm)
H-3	12.3 years	19	0.6
C-14	5730 years	156	24.0
S-35	87.5 days	167	24.0
P-33	25.3 days	249	46.0

Low energy beta emitters do not present an external exposure hazard since they cannot penetrate the dead layer of the skin. However, internal contamination is should be avoided since some of these compound have an affinity for certain target organs and can impart significant doses to these organs.

No special shielding is required since these isotopes do not present an external exposure hazard; i.e. the vials, syringes, etc. used to hold the isotopes provide sufficient shielding to stop all these low energy beta emitters (see figure 1).

(a) (b)

Figure 14.1. Examples of low energy beta emitters shielding. (a) vials, (b) syringes.

High energy beta emitters

Table 14.2. Examples of high energy beta emitters.

Isotope	Half-life	Energy (E_{max}) in MeV	Max. Range in Air (cm)
P-32	14.3 days	1.71	790
Cl-36	301,000 years	0.71	200

High energy beta emitters present both external and internal hazard. Their penetrating power is in between the low energy beta emitters and the gamma emitters; i.e. they can penetrate through the deep layer of the skin depositing a significant amount of energy and resulting in significant radiation dose.

Shielding of high energy beta emitters consists of low-Z materials such as plastic to minimize the emission of Bremsstrahlung radiation. However, when dealing with large quantities of high energy beta emitters (e.g. above 370 MBq), a thin sheet of high-Z material such as lead may be placed on the outside of the low-Z material (plastic) to absorb the Bremsstrahlung radiation produced in the low-Z material. **Note: it is very important to NEVER place the high-Z material in front of the low-Z material**. Examples of high energy beta emitters shielding are shown in Figure 14.2 and 14.3.

(a) (b) (c)

Figure 14.2. Examples of high energy beta emitters shielding. (a) syringe shield, (b) Perspex shield, (c) beta box.

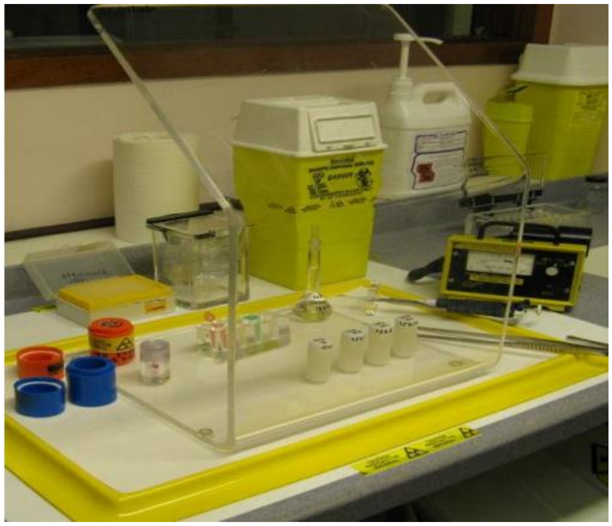


Figure 14.3. Examples of workbench set-up for P-32 work.

Low and medium energy gamma emitters

Table 3. Examples of low and medium energy gamma emitters.

Isotope	Half-life	Energy (E_{max}) in keV
I-125	60 days	35
Xe-133	5.25 days	81
Co-57	271 days	136

Low and medium energy gamma emitters present a risk of external and internal exposure. The gamma rays emitted should be shielded using thin layers of high-Z materials such as lead. Examples of low and medium energy gamma emitters shielding are shown in Figure 14.3.

High energy gamma emitters

Table 4. Examples of high energy gamma emitters.

Isotope	Half-life	Energy (Emax) in Mev
Na-22	2.6 years	1.275
Fe-59	44 days	1.290

Shielding of high-energy gamma emitters is achieved using thicker layer of high-Z materials such as lead bricks. In addition, remote handling tools should be considered to reduce the radiation dose. Examples of high-energy gamma emitters shielding are shown in Figure 14.4.

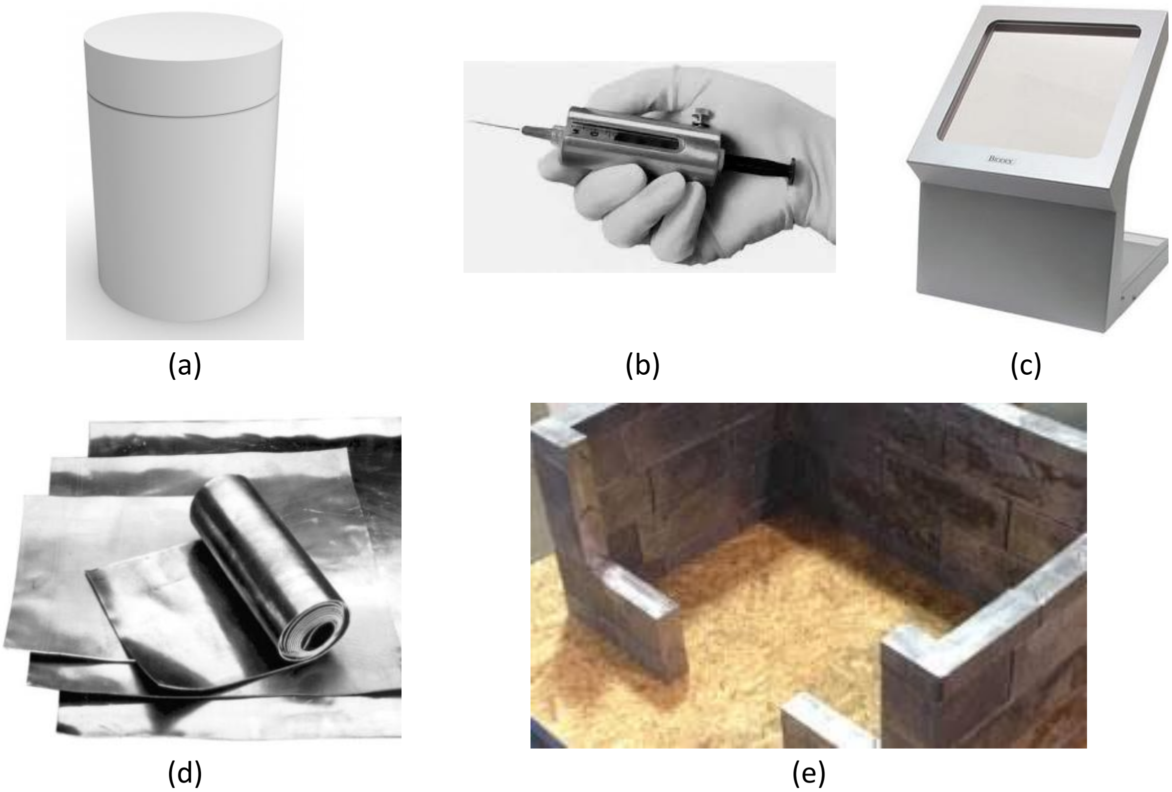


Figure 14.4. Examples of high energy gamma emitters shielding. (a) lead pot vial shield, (b) syringe shield, (c) workbench lead shield, (d) lead sheets, (e) lead bricks for high energy gamma emitters shielding.

For any questions or additional information on the most appropriate shielding for various isotopes, please contact the RSO at (*hse@kaust.edu.sa*).

16. Appendix 3. Radiation Spill Kit Content

The following items should be included in a spill kit:

- Radioactive warning signs and tape
- Plastic waste bags (various sizes)
- Identification tags
- Masking tape
- Forceps and tongs (various length)
- Disposable gloves (various sizes)
- Disposable lab coats
- Safety glasses
- Overshoes
- Disposable absorbent paper
- Scissors
- Marker pen and paper
- Decontamination solution
- Hand soap
- Sponge and nail brush
- Paper towel
- Personal decontamination procedure
- Emergency procedures
- Contamination monitor
- Swabs and small plastic vials for use with LSC

17. Appendix 4. Isotopes Safety Data Sheet

H-3 ISOTOPE SAFETY DATA SHEET

H-3	1 proton	2 neutrons

PHYSICAL DATA

Physical Half-Life 12.3 years or 4490 days

Type of Decay Beta minus (b^{-})

Major Betas

Max E (MeV)	Avg E (MeV)	# per 100 dis
0.0186	0.0057	100

Major Gammas

E (MeV)	# per 100 dis
-	-

Max Beta Range in Air: 6 mm

Max Beta Range in Water: 0.006 mm

Average Gamma E: N/A

RADIATION HAZARD

Exposure Route Internal exposure (ingestion, inhalation, puncture, wound, skin contamination)

Contamination skin dose (dispersed 1 cm^{2})	Negligible	
Contamination skin dose (droplet 0.05 ml)	Negligible	
Min. Ingestion ALI	480 MBq	
Min. Inhalation ALI	490 MBq	
Committed Effective Dose per Unit Intake (Sv.Bq^{-1})	Ingestion	Inhalation
H-3 water	1.8´10^{-11}	1.8´10^{-11}
Organic bound H-3	4.2´10^{-11}	4.1´10^{-11}

DOSIMETRY MONITORING

No external radiation monitoring necessary.
The need for internal radiation monitoring (via bioassay) will be determined by the RSO.

SHIELDING

None Required – The vial holding the isotope will provide sufficient shielding to stop the betas.

MONITORING METHOD FOR CONTAMINATION

Wipe Survey and Liquid Scintillation Counting analysis (65% efficiency).
NOTE: Thin-window Geiger-Mueller or NaI(Tl) scintillation counter will not detect Tritium.

SPECIAL PRECAUTIONS

- Consider wearing two pairs of gloves and change gloves frequently.
- Regular wipe surveys of the work areas should be undertaken where H-3 is used since Geiger-Mueller meters are not efficient.
- Place previously opened containers of tritiated water into a fume hood, not a refrigerator.
- DNA precursors (e.g. H-3 thymidine) are regarded as more toxic than tritiated water. Avoid risk of contamination by wearing double gloves.
- Monitor storage areas where large quantities of H-3 are kept, as H-3 may exchange with the hydrogen in plastic container or in water from ice build-up in fridge/freezer.
- Experiment involving the use of 50 MBq of H-3 or more should be performed in a Controlled Area.
- Segregate wastes to those with H-3 and C-14 only. Do not correct wastes for radioactive decay.

C-14	ISOTOPE SAFETY DATA SHEET

C-14	6 protons	8 neutrons

PHYSICAL DATA

Physical Half-Life 5730 years or 2.09´10^{6} days

Type of Decay Beta minus (b^{-})

Major Betas

Max E (MeV)	Avg E (MeV)	# per 100 dis
0.156	0.049	100

Major Gammas

E (MeV)	# per 100 dis
-	-

Max Beta Range in Air: 24 cm

Max Beta Range in Water: 0.28 mm

Average Gamma E: N/A

RADIATION HAZARD

Exposure Route Internal exposure (ingestion, inhalation, puncture, wound, skin contamination)

Contamination skin dose (dispersed 1 cm^2) 320 µSv.h^{-1} per kBq

Contamination skin dose (droplet 0.05 ml) 2.7 µSv.h^{-1} per kBq

Min. Ingestion ALI 34 MBq

Min. Inhalation ALI 34 MBq

Committed Effective Dose per Unit Intake (Sv.Bq^{-1})	Ingestion	Inhalation *(Vapor)*	Inhalation *(dioxide)*
Organic compound	5.8´10^{-10}	5.8´10^{-10}	6.2´10^{-12}

DOSIMETRY MONITORING

No external radiation monitoring necessary.

The need for internal radiation monitoring (via bioassay) will be determined by the RSO.

SHIELDING

None required - The vial holding the isotope should provide sufficient shielding to stop the betas.

Maximum Range for Beta	Plastic	0.3 mm
	Glass	0.2 mm

MONITORING METHOD FOR CONTAMINATION

Wipe survey and Liquid Scintillation Counting analysis (85% efficiency).

Thin-window Geiger-Mueller or Beta scintillation counters can be used (2% efficiency).

SPECIAL PRECAUTIONS

- Some organic compound can be absorbed through the glove and skin. Handle such compound remotely (e.g. forceps), wear two pairs of gloves and change the outer glove frequently.
- Do not cover the thin-window of the Geiger-Mueller survey meter with a plastic cap as it will not be able to detect low energy betas emitted by C-14.
- Use plastic shielding. Do not use lead shielding, which leads to Bremsstrahlung radiation.
- Work that generate carbon dioxide should be performed in fume hoods to prevent risk of inhalation.
- Experiment involving the use of 50 MBq of C-14 or more should be performed in a Controlled Area.
- Segregate wastes to those with H-3 and C-14 only. Do not correct waste for radioactive decay.

P-32	**ISOTOPE SAFETY DATA SHEET**

P-32 | **15 protons** | **17 neutrons**

PHYSICAL DATA

Physical Half-Life 14.3 days
Type of Decay Beta minus (b⁻)

Major Betas

Max E (MeV)	Avg E (MeV)	# per 100 dis
1.710	0.695	100

Major Gammas

E (MeV)	# per 100 dis
-	-

Max Beta Range in Air: 790 cm
Max Beta Range in Water: 0.8 cm

Average Gamma E: N/A

RADIATION HAZARD

Exposure Route Internal exposure (ingestion, inhalation, puncture, wound, skin contamination)

Contamination skin dose (dispersed 1 cm^2) 1.9 mSv.h^{-1} per kBq
Contamination skin dose (droplet 0.05 ml) 1.3 mSv.h^{-1} per kBq
Min. Ingestion ALI 8.3 MBq
Min. Inhalation ALI 6.3 MBq

Committed Effective Dose per Unit Intake (Sv.Bq^{-1})	**Ingestion**	**Inhalation** *(5 µm)*
All compounds	2.4´10^{-9}	1.1´10^{-9}

DOSIMETRY MONITORING

Thermoluminescent (TLD) whole-body and extremity (ring) dosimeter badges are required.
The need for internal radiation monitoring (via bioassay) will be determined by the RSO.

SHIELDING

Use low-Z material. Additional lead shielding may be required outside the low-Z material to attenuate Bremsstrahlung radiation.

Maximum Range for Beta		
	Plastic	6.3 mm
	Glass	3.4 mm

MONITORING METHOD FOR CONTAMINATION

Geiger-Mueller Counter (10-25% efficiency).
Wipe survey and Liquid Scintillation Counter analysis (85% efficiency).

SPECIAL PRECAUTIONS

- Handle P-32 remotely (e.g. forceps), wear two pairs of gloves and change the outer glove frequently. Do not handle unshielded vial with hands.
- Whole body and ring dosimeter must be worn when handling P-32.
- Monitor hands and work area during and immediately after work done with P-32.
- Work and store P-32 (including waste) behind plastic shielding (~1 cm thick). Use Geiger-Mueller counter to check the adequacy of the shielding and apply lead shielding outside the plastic shield if the dose rate is still too high.
- P-32 tends to attach to ferrous materials and glass, weak HCl can facilitate removal from surfaces.
- Segregate wastes to those with half-lives less than 90 days.

P-33	ISOTOPE SAFETY DATA SHEET

P-33 | **15 protons** | **18 neutrons**

PHYSICAL DATA

Physical Half-Life 25.3 days
Type of Decay Beta minus (b^{-})

Major Betas

Max E (MeV)	Avg E (MeV)	# per 100 dis
0.249	0.077	100

Major Gammas

E (MeV)	# per 100 dis
-	-

Max Beta Range in Air: 46 cm
Max Beta Range in Water: 0.6 mm

Average Gamma E: N/A

RADIATION HAZARD

Exposure Route Internal exposure (ingestion, inhalation, puncture, wound, skin contamination)

Contamination skin dose (dispersed 1 cm^2)	860 µSv.h^{-1} per kBq
Contamination skin dose (droplet 0.05 ml)	140 µSv.h^{-1} per kBq
Min. Ingestion ALI	83 MBq
Min. Inhalation ALI	14 MBq

Committed Effective Dose per Unit Intake (Sv.Bq^{-1})	**Ingestion**	**Inhalation** *(5 µm)*
All compounds	2.4´10^{-10}	1.4´10^{-10}

DOSIMETRY MONITORING

Thermoluminescent (TLD) whole-body and extremity (ring) dosimeter badges are required.
The need for internal radiation monitoring (via bioassay) will be determined by the RSO.

SHIELDING

None required - The vial holding the isotope should provide sufficient shielding to stop the betas.

Maximum Range for Beta	Plastic	0.5 mm
	Glass	0.3 mm

MONITORING METHOD FOR CONTAMINATION

Geiger-Mueller Counter (20% efficiency).
Wipe survey and Liquid Scintillation Counter analysis (85% efficiency).

SPECIAL PRECAUTIONS

- P-33 can penetrate through the glove and skin. Handle P-33 remotely (e.g. forceps), wear two pairs of gloves and change the outer glove frequently.
- Whole body and ring dosimeter must be worn when handling P-33.
- Work and store P-33 (including waste) behind plastic shielding (~1 cm thick). Use Geiger-Mueller survey meter to check the adequacy of the shielding.
- Mild acids such as white vinegar are good decontamination solution for P-33 in most common chemical forms.
- Segregate wastes to those with half-lives less than 90 days.

Cl-36	ISOTOPE SAFETY DATA SHEET

Cl-36	17 protons	19 neutrons

PHYSICAL DATA

Physical Half-Life 301,000 years or 1.1´10⁸ days
Type of Decay Beta minus (b⁻)

Major Betas

Max E (MeV)	Avg E (MeV)	# per 100 dis
0.710	0.251	100

Major Gammas

E (MeV)	# per 100 dis
-	-

Max Beta Range in Air: 200 cm
Max Beta Range in Water: 2.6 mm

Average Gamma E: N/A

RADIATION HAZARD

Exposure Route Internal exposure (ingestion, inhalation, puncture, wound, skin contamination)

Contamination skin dose (dispersed 1 cm^2)	1.8 mSv.h^{-1} per kBq
Contamination skin dose (droplet 0.05 ml)	770 µSv.h^{-1} per kBq
Min. Ingestion ALI	22 MBq
Min. Inhalation ALI	2.9 MBq

Committed Effective Dose per Unit Intake (Sv.Bq^{-1})

	Ingestion	Inhalation *(5 µm)*
All compounds	9.3´10^{-10}	4.9´10^{-10}

DOSIMETRY MONITORING

Thermoluminescent whole-body and extremity (ring) dosimeter badges are required.
The need for internal radiation monitoring (via bioassay) will be determined by the RSO

SHIELDING

Use low-Z materials. Additional lead shielding may be required outside the low-Z material shielding to attenuate Bremsstrahlung radiation.

Maximum Range for Beta	Plastic	2.0 mm
	Glass	1.1 mm

MONITORING METHOD FOR CONTAMINATION

Thin window Geiger-Mueller Counter (20% efficiency).
Wipe survey and Liquid Scintillation Counter analysis (85% efficiency).

SPECIAL PRECAUTIONS

- Cl-36 can penetrate through the glove and skin. Handle Cl-36 remotely (e.g. forceps), wear two pairs of gloves and change the outer glove frequently.
- Whole body and ring dosimeter must be worn when handling Cl-36.
- Work and store Cl-36 (including waste) behind low-Z material shielding. Use Geiger-Mueller survey meter to check the adequacy of the shielding and add lead shielding outside the low-Z shield if the dose rate is still too high.
- Segregate wastes to those with long half-lives but not with H-3 and C-14 waste. Do not correct Cl-36 wastes for radioactive decay.

Na-22	ISOTOPE SAFETY DATA SHEET

Na-22	11 protons	11 neutrons

PHYSICAL DATA

Physical Half-Life 2.6 years or 951 days
Type of Decay Beta plus (b^+)

Major Betas

Max E (MeV)	Avg E (MeV)	# per 100 dis
0.546	0.216	90

Major Gammas

E (MeV)	# per 100 dis
1.275	100

Max Beta Range in Air: 140 cm
Max Beta Range in Water: 1.85 mm

Average Gamma E: 0.784 MeV

RADIATION HAZARD

Exposure Route Internal exposure (ingestion, inhalation, puncture, wound, skin contamination)
External radiation exposure

Contamination skin dose (dispersed 1 cm^2)	1.7 mSv.h^{-1} per kBq
Contamination skin dose (droplet 0.05 ml)	670 µSv.h^{-1} per kBq
Min. Ingestion ALI	6.3 MBq
Min. Inhalation ALI	10 MBq

Committed Effective Dose per Unit Intake (Sv.Bq^{-1})	Ingestion	Inhalation *(5 µm)*
All compounds	3.2´10^{-9}	2.0´10^{-9}

DOSIMETRY MONITORING

Thermoluminescent whole-body and extremity (ring) dosimeter badges are required.
The need for internal radiation monitoring (via bioassay) will be determined by the RSO.

SHIELDING

Shield with low-atomic number materials. Addition of lead shielding may be required outside the low-atomic number material shielding to attenuate Bremsstrahlung radiation.

Maximum Range for Beta	Plastic	1.4 mm
	Glass	0.8 mm
Tenth Value Layer for average gamma	Lead	37 mm

MONITORING METHOD FOR CONTAMINATION

Thin window Geiger-Mueller counter (20% efficiency).
NaI(Tl) scintillation counter is best for detecting Na-22 gamma radiation (30-60% efficiency).
Wipe survey and Liquid Scintillation Counter analysis (85% efficiency).

SPECIAL PRECAUTIONS

- Handle Na-22 remotely (e.g. forceps), wear two pairs of gloves and change the outer glove frequently.
- Whole body and ring dosimeter must be worn when handling Na-22.
- Work and store Na-22 (including waste) behind lead or high-Z material shielding.
- Segregate wastes to those with long half-lives (more than 90 days)

S-35	ISOTOPE SAFETY DATA SHEET

S-35	16 protons	19 neutrons

PHYSICAL DATA

Physical Half-Life 87.5 days
Type of Decay Beta minus (b^-)

Major Betas

Max E (MeV)	Avg E (MeV)	# per 100 dis
0.167	0.049	100

Major Gammas

E (MeV)	# per 100 dis
-	-

Max Beta Range in Air: 24 cm
Max Beta Range in Water: 0.32 mm

Average Gamma E: N/A

RADIATION HAZARD

Exposure Route Internal exposure (ingestion, inhalation, puncture, wound, skin contamination)

Contamination skin dose (dispersed 1 cm^2)	350 µSv.h^{-1} per kBq
Contamination skin dose (droplet 0.05 ml)	4.1 µSv.h^{-1} per kBq
Min. Ingestion ALI	26 MBq
Min. Inhalation ALI	15 MBq

Committed Effective Dose per Unit Intake (Sv.Bq^{-1})

	Ingestion	Inhalation *(5 µm)*
Inorganic compound	1.4´10^{-10}	-
Sulphid. & Sulphat.	-	8.0´10^{-11}

DOSIMETRY MONITORING

No external radiation monitoring necessary.
The need for internal radiation monitoring (via bioassay) will be determined by the RSO.

SHIELDING

None required - The vial holding the isotope will provide sufficient shielding to stop the betas.

Maximum Range for Beta	Plastic	0.3 mm
	Glass	0.2 mm

MONITORING METHOD FOR CONTAMINATION

Thin window Geiger-Mueller counter (3-10% efficiency).
Wipe survey and Liquid Scintillation Counting analysis (85% efficiency).

SPECIAL PRECAUTIONS

- Handle S-35 remotely (e.g. forceps), wear two pairs of gloves and change the outer glove frequently.
- Segregate wastes to those with half-lives shorter than 90 days.
- Vials should be opened in a fume hood or through an activated charcoal filter. Volatile impurities are generally small (0.05%).
- S-35 may be difficult to distinguish from C-14 because of beta emissions are of similar energies. If they are used in the same area, controls should be established to prevent confusion.
- Care should be taken not to generate sulphur dioxide or hydrogen sulphide which could be inhaled.

18. Appendix 5. Uranyl Compounds Safety information sheet

Physical Characteristics

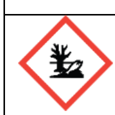
HALF-LIFE: 4.5×10^9 y
Type Decay: alpha, beta
Hazard Category: C- level (low hazard) : 100 µCi to 10 mCi
B - level (Moderate hazard) : > 10 mCi to 1 C
A - level (High hazard) : greater than 1 Ci

Uranyl acetate and uranyl nitrate are water---soluble uranium compounds and are often used as stains in electron microscopy. Even with the relatively small amounts used in microscopy, there are associated chemical and radiological hazards which require some basic safety precautions to be adopted; with the emphasis on avoiding the possibility of inhalation or ingestion of the material.

Radiology & toxicology hazards

Uranyl acetate and uranyl nitrate principally contain the isotope U-238 of uranium. The specific activity of U-238 in laboratory grade uranium chemicals does not exceed 10,000 Bq per gram (where Bq refers to disintegrations per second) and the amount of gamma rays produced is very low. U-238 is an alpha emitter and there are also beta and gamma emitting decay products.

HAZARDS

	Acutely toxic if swallowed or inhaled.
	May cause damage to organs through prolonged or repeated exposure.
	Toxic to aquatic life with long lasting effects.

External radiation hazard

Typical laboratory quantities of uranium salts do not represent a significant external radiation hazard, as alpha particles do not penetrate the external dead layer of skin. There is beta and gamma emitters in the U-238 decay chain, but the beta particles also do not have enough energy to penetrate the skin, and the amount of gamma radiation is minimal.

Inhalation or ingestion hazard

The primary radiological hazard arises from inhalation or ingestion of the uranium compound, which leads to irradiation of lung and bone cells causing an increased risk of cancer. A chemical hazard also arises from inhalation or ingestion, as uranium is a heavy metal and can damage the kidneys. Absorption through the skin is not significant but contact with the substance can cause irritation and increases the risk of ingestion.

Overall, there is a minimal external risk from the radiation emitted by uranyl acetate and uranyl nitrate, and a relatively large risk arising from internal exposure following inhalation or ingestion. It is therefore essential to adopt appropriate controls when handling unsealed uranium salts to minimize this risk:

- Reduce the amount being handled as much as possible
- Contain the unsealed sources to prevent contamination
- Maintain a high level of cleanliness.
- Exert general hazard control and apply safe working practices

With the most serious hazard arising from inhalation or ingestion, extra care should be taken to prevent any possibility of inhaling fine particles. Gloves must always be worn when handling or weighing out the uranium salts. Under normal circumstances when using the compound infrequently and working with small quantities of up to 5g, respiratory protection is not necessary. Avoid contamination of bench surfaces by using spill trays (metal or plastic) with disposable coverings such as bench coat and clean the surface after use. If an appropriate thin window GM tube survey meter is available, then it can be used to monitor for contamination. Apply the same principles when working in solution.

Storage

Any stock solution or powder must be labeled with the radioactive warning sign and stored in a locked cabinet or refrigerator. Lead shielding is not necessary as the storage cabinet easily contains the radiation. Very old containers that have remained unopened may contain significant levels of radon (a radioactive gas) and should be opened with caution, in a fume hood. Storage conditions are intended to provide control and security; therefore, access should only be given to appropriate persons who have been made aware of the safety requirements.

Disposal of waste

Solid waste

Solid (dry) waste contaminated with uranyl acetate, such as paper towels, pipettes, gloves and other PPE must be double bagged in a clear plastic bag, labelled and disposed of as radioactive waste.

Liquid waste

UA compounds liquid waste disposal is regulated as radioactive waste. Uranyl Acetate and Uranyl Nitrate liquid wastes should be collected separately. Refrain from mixing staining compounds, hazardous chemicals, or solvents with Uranyl Acetate or Uranyl Nitrate.
Liquids should be poured into a labeled radioactive liquid waste container and stored in the designated fume hood. Contact HSE radiation safety for the UA radioactive waste pickup.

Disposal

- All radioactive waste containers must be labeled with a Radioactive Waste Tag.

- Once your waste container is full and ready to be disposed of, please fill in the *Radioactive Waste Pick-Up Form* (Appendix 2) and raise a general request for radioactive waste disposal on SALUTE system (attach the form with the request).

- The RSO will arrange a time to meet to collect the waste at your laboratory.

Emergency Procedures

First Aid

SKIN CONTACT

- Flush skin with tepid water and soap for 15 minutes using the closest available sink, portable drench hose or safety shower.
- Call 911 on a landline phone or 012 808 0911 if calling on a mobile phone for medical assistance

EYE CONTACT

- Using eyewash, flush eyes while hold eyelid open and away from exposed eye for 15 minutes.
- Call 911 on a landline phone or 012 808 0911 if calling on a mobile phone for medical assistance
- Continue flushing with water until emergency medical personnel arrive.

INHALATION

- If dust or vapors are inhaled, immediately move to get fresh air. If possible, force coughing and blowing of the nose.
- If respiratory irritation occurs call 911 on a landline phone or 012 808 0911 if calling on a mobile phone for medical assistance

INGESTION

- Rinse mouth with water.
- Call 911 on a landline phone or 012 808 0911 if calling on a mobile phone for medical assistance

Spill Response

For incidental powder spills:

- Cover the area with a moist paper towel to prevent dispersal of the powder.
- Wearing the proper PPE, sweep up the powder using paper towels or wipes and dispose of in the radioactive solid waste container.
- Survey the area with a Geiger counter and notify the RSO if the count rate is significantly higher than background.

For incidental liquid spills:

- Wearing the proper PPE, absorb the spill into the benchtop liner or other absorbent material and dispose of in the radioactive solid waste container.
- Foaming soap cleaners may be used to clean liquids that have dried onto a benchtop.

Survey the area with a Geiger counter and notify the RSO if the count rate is significantly higher than background.

Record Keeping/Trending

The final copy of the approved Radiation Safety Manual is kept on the policy Tech, Research Compliance website, and the HSE share Point.

Management of Change

This document should be reviewed every three years or when deemed necessary by the Radiation Safety Officer (RSO).

References

- KAUST Radiation Safety Program Website

Legislative Framework

- The Law on Nuclear and Radiological Control
- The Law on Civil Liability for Nuclear Damage
- The Status of the Nuclear and Radiological Regulatory Commission (NRRC)

Technical Regulations

- (NRRC-R-01) Radiation Safety
- (NRRC-R-02) Notification on and Authorization of Facilities and Activities with Radiation Sources
- (NRRC-R-03) Licensing and Regulatory Oversight of Nuclear Facilities
- (NRRC-R-04) Leadership and Management for Safety
- (NRRC-R-07) Safety Assessment of Nuclear Facilities
- (NRRC-R-12) Nuclear Material Accountancy and Control
- (NRRC-R-14) Nuclear Facilities Emergency Preparedness and Response
- (NRRC-R-16) Management of Radioactive Waste
- (NRRC-R-17) Security of Radioactive Materials
- (NRRC-R-17) Security of Radioactive Materials

Help

Questions about this procedure? Contact hse@kaust.edu.sa

Document History & Revision Status

Date	Revision	Prepared by	Description of change
September 2014	00	C Davey	Initial Document
September 2018	01	D Darios & M Bahmaid	Major rewrite
October 2018	02	D Darios & M Bahmaid	Draft for Approval.
June 2021	03	M Bahmaid	Thorough Revision
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