Radiological Safety Manual

Version 11 – 2023

DOCUMENT CONTROL

The Chair of the Radiation Protection Advisory Committee (RPAC) holds original copies of this document. Substantial changes to the document must be agreed collectively by the members of the TU Dublin RPAC, Health and Safety Committee and ratified by the TU Dublin Safety, Health and Welfare Steering Committee; however, minor changes may need to be made from time to time by the RPO.

Changes will be reflected in a change of the version number of the document (which will change to *Version (i)-Y*, where *Y* refers to the year in which the change is made). The previous version of the Safety Manual will be revoked after all changes have been made. The RPO (City Campus) holds a copy of all obsolete versions of the document marked ‘OBSOLETE’ for document retention purposes.

Contents

1 SECTION – TU DUBLIN LICENSED ITEMS

1.0 Introduction

In this section a list of all licensed items currently held on TU Dublin property is provided as well as their location. The categories of licensed items are sealed and unsealed radioactive materials, and instruments capable of producing ionising radiation.

1.1 Overview of the Interaction of Radiation with Matter

The transfer of energy from the emitted particle or photon to an absorbing medium has several mechanisms. These mechanisms result in ionisation and excitation of atoms or molecules in the absorber. The transferred energy is eventually dissipated as heat. *Ionisation* is the removal of an orbital electron from an atom or molecule, creating a positively charged ion. In order to cause an ionisation, the radiation must transfer enough energy to the electron to overcome the binding force on the electron. The ejection of an electron from a molecule can cause dissociation of the molecule.

Excitation is the addition of energy to an orbital electron, thereby transferring the atom or molecule from the ground state to an excited state.

1.2 X-Ray Units

The following are the X-ray units on the TU Dublin EPA licence:

(a) Undergraduate Low KeV X-ray Unit

The Leybold Didactic closed X-ray system is held within laboratory CQ-123, Central Quad Grangegorman and is used for the purposes of undergraduate laboratories in 3rd and 4th year of the School of Physics courses. The Leybold Didactic closed X-ray system operates between 0 kV - 35 kV with a tube current of 0 mA – 1 mA.

(b) Research Rigaku X-ray Device (XRD)

The Rigaku MiniFlex 600 X-ray diffractometer (XRD) that is sited in room B.09.0 of the basement of the FOCAS Research Institute, Camden Row is an analytical x-ray device used mainly for analysing the structure and properties of solid materials including powders, thin films, polymers and metals. The maximum tube voltage of this diffractometer is 40 kVp and maximum tube current is 15mA.

(c) Research X-ray Fluorescence unit (XRF)

The Bruker Tracer 5g Fluorescence unit that is sited in room B.18.0 of the basement of the FOCAS Research Institute, Camden Row is a mobile non-destructive x-ray device used mainly for analysing the structure and properties of solid and mid-density materials. It has a range of x-ray generation from 6 – 50kV with 5 - 195µA current and max 4 Watt output.

1.3 Radioactive Material

Custody and Use Radioactive Teaching Material

The following is a list of sealed radioactive material in the possession of TU Dublin which are currently in use. These sources are locked in a Perspex and Lead Lined Safe in room CQ-123.

Table 1.1 : Sources for Teaching (Stored in BriTec Safe in CQ-123)

Source	Activity	Label
Am-241	1850 kBq	Metal
Sr-90-1	333 kBq	S4
Sr-90-2	185 kBq	SR-90 (metal)
Co-60-1	37 kBq	October 2011 (Spectrum Techniques)
Co-60-2	37 kBq	October 2011 (Spectrum Techniques)
Co-60-3	37 kBq	October 2011 (Spectrum Techniques)
Co-60-4	37 kBq	October 2011 (Spectrum Techniques)
Co-60-5	37 kBq	October 2011 (Spectrum Techniques)
Co-60-6	37 kBq	October 2011 (Spectrum Techniques)
Co-60-7	37 kBq	October 2011 (Spectrum Techniques)
Co-60-8	37 kBq	October 2011 (Spectrum Techniques)
Cs-137-1	37 kBq	September 2011 (Spectrum Techniques)
Cs-137-2	37 kBq	September 2011 (Spectrum Techniques)
Cs-137 -3	370 kBq	CS2
Co-60 -9	185 kBq	Metal
Co-60 –T1	37 kBq	October 2011 (Spectrum Techniques)
Co-57-T2	37 kBq	September 2018 (Spectrum Techniques)
Cs-137-T3	3.7 kBq	October 2011 (Spectrum Techniques)
Mn-54-T4	37 kBq	September 2018 (Spectrum Techniques)
Na-22 –T5	37 kBq	September 2018 (Spectrum Techniques)
Cd-109-T6	37 kBq	September 2018 (Spectrum Techniques)
Ba-133-T7	37 kBq	October 2011 (Spectrum Techniques)
Zn-65-T8	37 kBq	September 2018 (Spectrum Techniques)
C-14	370 kBq	September 2013 (Spectrum Techniques)
Am-241	9.5 kBq	Metal

Custody and Use Radioactive Research Material

The following is a list of currently licensed sources of ionising radiation in the possession of TU Dublin, classed as being for “Custody and Use”:

Table 1.2 : Inventory of Custody and Use Radioactive Sources for Research Purposes (Stored in Large floor Safe in Room CQ-123)

Source	Type	Label
Uranyl Acetate* (25g)	U	Agar Scientific

Type: U= Unsealed source, S=Sealed (*Custody and use)

2 SECTION – NORMAL OPERATING PROCEDURES

2.1 General Regulations Regarding the Custody and Use of Sources of Ionising Radiation and Equipment Capable of Producing Ionising Radiation

All custody and use research sources are secured in a large floor safe in room CQ-123 in the TU Dublin Central Quad Grangegorman Campus. Quarterly visual inspections are to be taken and the results held for inspection by EPA representatives.

All custody and use teaching sources are secured in the BriTec Benchtop safe in room CQ-123 in the TU Dublin Central Quad Grangegorman Campus. Biennial wipe tests are conducted on all sealed sources and appropriate records of these tests kept by the RPO (City Campus). Monthly visual inspections are carried out and the results held for inspection by EPA representatives.

All equipment capable of producing ionising radiation is securely located in either room CQ-123 or in the FOCAS Research Institute. Monthly visual inspections are carried out on the Research Analytical X-ray Devices and annual inspections are carried out on the Undergraduate Unit and the results held for inspection by EPA representatives.

2.2 Authorisation to Use Radioactive Material or Sources of Ionising Radiation

2.2.1 Permit Application for Possession and Use of Radioactive Material or Sources of Ionising Radiation within TU Dublin

Academic and research staff who wish to acquire and use radioactive materials or sources of ionising radiation must submit a TU Dublin Radiation Permit Application Form for the *Application for Possession and Use of Radioactive Materials / Sources of Ionising Radiation* to the Radiation Protection Advisory Committee (RPAC) via the City Campus Radiation Protection Officer (RPO – Jane Torris jane.torris@TUDublin.ie). A training log and details of any previous experience for use of radioactive material must accompany the application form for new academic or research staff.

Each application must be completed in sufficient detail for the Committee's evaluation:

- Applications must include the name of the academic or research staff, the radionuclide or source of ionising radiation, the chemical or physical forms, the amount for use per experiment and the maximum daily order limits.
- An experiment protocol must accompany each application, describing precautions to avoid the inadvertent release or ingestion/inhalation of radioactive material.

- A risk assessment should be completed in consultation with the RPO and must accompany the application.
- Name any hazardous chemicals and compounds in addition to the radionuclide that will be used in the experiment.
- The RPAC may require additional information such as facility design, type of radiation detection equipment, emergency procedures, waste disposal methods, take-back of radioactive material by company, funds for disposal of the radioactive material and any relevant training and experience of personnel.

Applications for TU Dublin permits for working with sources of ionising radiation and a guide for completing them are available from the RPAC. The RPO will assist applicants in completing the application.

2.2.2 Amendment to TU Dublin Permit

A request for amendment to an approved TU Dublin permit is submitted as above on the form *Request for Amendment to TU Dublin Permit for Possession and Use of Radioactive Materials* available from the RPO. Amendment requests may be made only for the following changes:

- Chemical/physical form
- Daily order limit
- Location of use
- Use procedure

2.2.3 Radioactive Material Use: Approval and TU Dublin Permit Authorisation

All applications for use of radioactive materials are reviewed by the RPAC and if approved the application is sent to the Environmental Protection Agency – Office of Radiological Protection (EPA) for inclusion on the University's licence. Upon approval by the EPA, a TU Dublin numbered permit is issued, listing any special conditions specified by the RPAC. The TU Dublin permit number is to be used when ordering materials and when amending or renewing the permit.

NOTE: It will generally take a minimum of 1 month to arrange for Committee approval and then the EPA may take 3 months. Applications **must** be submitted prior to ordering any radioactive material or sources of ionising radiation. The University's licence must be updated by the EPA before the material can be accepted onto the University's property. Failure to adhere to this could result in the University being fined or losing it's licence to carry out work involving sources of ionising radiation and also disciplinary procedures being taken against the staff member who took the unauthorised action.

DISCIPLINARY ACTION
Any member of staff/student who contravenes or fails to manage to work in accordance with current Statutory Instrument No. 30 of 2019 legislation (EPA), the TU Dublin Framework Safety Statement and Codes of Practice will be subject to relevant TU Dublin disciplinary procedure. The Buildings Officer will address any contraventions by contractors/service providers.

2.2.4 Renewal of TU Dublin Permit

TU Dublin permits for working with sources of ionising radiation are valid for three years, however, each permit holder must inform the RPAC at the beginning of each academic year that they intend to use their TU Dublin permit in the coming academic year.

The academic or research staff should identify the status of each TU Dublin permit. For example, they should:

- Review all information associated with their permit for accuracy.
- Indicate status of each permit and if changes are to be made in location of use or the use procedure. (Amendment request must be submitted for these changes.)
- Perform a physical inventory of unused radioactive materials and provide an accurate inventory for each permit.
- Submit a new application for TU Dublin permits that will expire at least four months prior to the end of the permit.
- Indicate disposition for the radioactive material if any permit is not to be renewed.
- This form and new applications must be completed and returned to the RPO (City Campus) four months prior to the expiration date for RPAC evaluation.

2.2.5 Radioactive Material Use: TU Dublin Permit Termination and Non-Compliance Policy

2.2.5.1 TU Dublin Permit Use Termination

At termination of a TU Dublin permit, all unused radioactive material must be accounted for and turned over to the RPO for storage and disposal.

Materials may be transferred to another authorised user upon approval by RPAC as described under TRANSFER OR SHIPMENT OF RADIOACTIVE MATERIAL.

Failure to annually renew a TU Dublin permit's use will result in automatic cancellation of the permit. To reactivate a cancelled TU Dublin permit, a new application must be submitted for RPAC review and approval.

2.2.5.2 Non-Compliance Policy

The following items of non-compliance will be brought to the attention of the RPO (City Campus). The RPO may recommend review by the RPAC for:

- Willful violation of the University's policies or the statutory regulations (EPA) regarding the use of radioactive materials.
- Loss or inability to account for radioactive material.
- Repeated mid or high level removable surface contamination if unsealed sources in use.
- Doses exceeding the TU Dublin administrative limits (see section 1).
- Improper use of radioactive materials which results in significantly endangering the safety of personnel or the environment.
- Use of radioactive materials not authorised by the permit.

Depending on the severity of the incident, the RPAC will take appropriate action including revocation of the permit and disciplinary action against the staff member.

2.3 Procurement and Transfer of Radioactive Materials

Radioactive material may be brought onto campus **only with the prior approval** of the RPAC and EPA.

All incoming radioactive material must be included in the University's licence and authorised by the RPAC and EPA. The steps for obtaining radioactive material are outlined below.

Only the Sources of Ionising Radiation specified in the University Licence from the EPA and in the amounts specified in the licence can be requisitioned, ordered or taken into TU Dublin Campuses.

2.3.1 Requisitioning

Sources of Ionising Radiation can only be requisitioned after written approval of the EPA which the University's RPO (City Campus) will apply for in consultation with the RPAC, and orders for same must be sanctioned by the relevant Head of School / Centre Managers.

TU Dublin Purchase Orders for ALL licensable sources of ionising radiation for use (whether research or otherwise) MUST be countersigned by the RPO/DRPO PRIOR to the purchase of the source being authorised. It is the responsibility of the budget signatory (i.e., Head of School / Centre Manager) to ensure that this occurs.

Sources of Ionising Radiation brought into TU Dublin from other institutions must have the prior approval of the Chair of the other institutions Radiation Protection Advisory Committee, the appropriate Head of School, the University Radiation Advisory Committee in TU Dublin and of the RPO of the other Institution.

This applies to source of ionising radiation that are licensable by the EPA or fall under the EPA licence conditions. The RPO must be informed prior to the transport and will obtain the necessary transport licence from the EPA as well as providing advice on protective measures that should be employed during transport, if required.

The removal of Sources of Ionising Radiation from TU Dublin Campuses in order to bring them to another institution or company must also have the prior approval of the Chair of the Radiation Protection Advisory Committee and the appropriate Head of School/Centre Director and the University RPO and the approval of both the RPO of the receiving institution (or company) and of the EPA.

Purchasing Procedure for Sources of Ionising Radiation:

1. Prior to the **purchase** or the receipt of **gifts** of sources of ionising radiation *(Solid, Powder or Liquid sources (alpha, beta or gamma) or Equipment containing sources of ionising radiation or capable of producing ionising radiation)* advice should be sought from the TU Dublin Radiation Protection Officer (RPO) or Deputy Radiation Protection Officer (DRPO).
2. An application for permission to carry out work involving any source of ionising radiation must be made to the Radiological Protection Advisory Committee (RPAC), this application should include a Risk Assessment and a Standard Operating Procedure. Following receipt of the necessary documentation the RPAC will review the application and if approved submit an application to the Environmental Protection Agency – Office of Radiological Protection (EPA) for an amendment of the University's licence to carry out said work.
3. The purchase of all sources of ionising radiation within TU Dublin Campuses must at all times be countersigned, or accompanied by sanctioning in writing, from the TU Dublin RPO or DRPO before being completed. EPA approval of such purchases can require investigation by the RPO/DRPO or consultation with the TU Dublin Radiation Protection Advisory Committee and therefore can take time from the receipt of the order. {Approximately 8 - 12 weeks}
4. When ordering an item of equipment or instrument, the purchaser of the item (i.e. the budget holder) must be satisfied, through querying with the supplier of the instrument or equipment, that the item does not contain a source of ionising radiation. If it is suspected that the device may contain a source of ionising radiation, the purchaser must contact the RPO or DRPO prior to the final sanctioning of the purchase.

5. The purchaser must also, in the case of sealed radioactive sources of ionising radiation, obtain a Wipe Test certificate and for all other types of sources of ionising radiation a written 'Take-Back Agreement' must be obtained from the supplier before taking receipt of the item. Furthermore, the purchaser must have sufficient funds in their budget to pay for the disposal of the relevant source of ionising radiation. This documentation must be presented to the RPO or DRPO at the time of placing the order of the item.

Statement for Tender Documentation Terms and Conditions:

When submitting a proposal, each supplier shall inform the University in writing of the presence or absence of sources on ionising radiation within the equipment. The supplier shall make all investigations and examinations to ascertain whether the equipment contains a source of ionising radiation if this is unknown. The supplier shall also, where the equipment contains a sealed source of ionising radiation, provide evidence of recent wipe testing and evidence of a 'take-back agreement' for same. Any queries in relation to this can be directed to the RPO or DRPO.

Summary of Information to accompany the requisition order form:

1) Signed and dated by person who has approval from the RPO to use the source.
2) Signed and dated by the Head of School/Centre Director or person deputising for the Head of School/Centre Director.
3) Initialled and dated by the RPO or deputy RPO.

Procedure 2.3.1 also applies to NON-PURCHASED MATERIAL (material that is from other researchers, free samples from venders, etc.)

2.3.2 Delivery/Receipt of Sources of Ionising Radiation

The person requisitioning the source must ensure that suitable and satisfactory arrangements are in place to receive the source on its arrival at TU Dublin (this may require checking with the supplier the means, date and time of delivery in order to make the necessary arrangements).

The source must be licensed for use by the EPA prior to delivery of the source, through the RPO who will prepare a schedule 2 amendment to the TU Dublin licence if the RPAC has authorised the work.

This EPA amendment must be confirmed before the source can be taken on to TU Dublin Campuses and used. The RPO requires the following information (which must be supplied by the person acquiring the source) in order to process this application:

- The manufacturer's wipe test certificate in respect of each sealed radioactive source;
- Written assurance from the manufacturer that each sealed source will be accepted back when no longer required by the University.

In the case where a source is being acquired to replace an existing source, arrangements must be made to ensure that the original source is returned to the manufacturer with prior written authorisation by the EPA and University RPAC.

When radioactive material is received, the following actions are taken:

- Containers are checked for damage or contamination.
- A check is made to ensure the order and that material is covered by a valid permit. Material not covered by a valid permit will not be released until a new permit is issued or a current permit is amended.
- An entry is made in the inventory file.
- For sealed sources the RPO will carry out a wipe test on the sealed sources of radioactive material.
- Material is delivered to user. If there are special time requirements, arrangements can be made to pick up the material from the RPO.

2.3.3 Storage and Use

If the source is radioactive (and not fixed), it must be stored in the protective storage facilities provided in the laboratory where the source is to be sited, or at another secure location (generally in the lead-lined safe in room CQ-123, or in the long-term storage in the floor safe in room CQ-123). A sign-out logbook (Table 2.1) is present at this location, which must be completed when the source is removed for use and returned to its secure location. The RPO as part of his/her duties has the right to inspect, examine or check the logbook or other appropriate details to ensure compliance with these regulations.

It is the responsibility of the Head of School or Centre Director to ensure that all persons who requisition a source or number of sources comply with these regulations.

2.3.4 Transfer or Shipment of Radioactive Material

Radioactive material may only be shipped from the campus or transferred to another group with the prior approval of RPAC.

Transfer to another TU Dublin Permit

The group in possession of the material must obtain approval from RPAC prior to transfer.

RPAC will verify material is covered by a valid permit issued to the receiving group and authorise transfer.

An entry is made in the inventory list.

2.4 General Policies and Procedures for Radionuclide Use in the Laboratory

2.4.1 Posting and Marking of Areas and Equipment

ENTRANCE

Each laboratory or area where radioactive materials are used or stored must be posted at the entrance with a *CAUTION RADIOACTIVE MATERIAL* sign. The sign must include the name and after-hours phone number of the Principal Investigator or designee. Entry warning signs are to be posted and removed only by Radiation Safety.

RADIOACTIVE MATERIAL WORK AREAS

Areas used for work with unsealed radioactive materials must be clearly marked with *CAUTION RADIOACTIVE MATERIAL* tape.

RADIATION AREA

Areas where radiation levels might expose a person to 5 millirem in any one hour must be posted with a *CAUTION RADIATION AREA* sign. (Fainic – Ábhar radaighníomhach in úsáid san áit seo / Caution – Radioactive material in use in this area). Equipment doors and covers need not be posted if radiation levels are high only when doors are open.

STORAGE AREAS AND CONTAINERS

Refrigerators, freezers, and other "in lab" storage areas and containers in which radioactive materials are stored or transported must have a visible *CAUTION RADIOACTIVE MATERIAL* label. Labels should be removed from containers that are empty and not contaminated.

EQUIPMENT

Laboratory equipment (flasks, beakers, centrifuges, etc.) containing radioactive materials should be marked with *CAUTION RADIOACTIVE MATERIAL* tape.

CONTAMINATED AREAS AND EQUIPMENT

Radiation Safety may mark areas and equipment to indicate significant levels of contamination found during surveys. These markings are to be removed only after the article or area has been decontaminated.

OTHER

Additional postings to control access or ensure safe operations.

2.4.2 Laboratory Safety Practices

Each permit lists the type of workplace, protective equipment and standard operating procedures required for use of sources of ionising radiation. In addition to the workplace requirements outlined for each activity in the following subsections, the following principles are always applicable:

CLOTHING

A lab coat or apron, disposable gloves, and appropriate eye protection should always be worn whenever unsealed sources of radioactive material are handled (even in tracer amounts).

NIL by MOUTH

Do not smoke, eat, store food, or apply cosmetics in any laboratory where sources of ionising radiation are used or stored. Do not pipette by mouth. Use self-adhesive labels only.

SECONDARY CONTAINERS

To avoid spills, use metal or plastic outer trays or beakers to carry liquid radioactive materials.

OPEN WOUNDS

Do not work with unsealed radioactive materials with open cuts, sores, etc. on exposed skin areas, even if bandaged.

WASHING

After handling radioactive materials, be sure to wash hands thoroughly before handling food, tobacco, etc.

WORK SURFACES

Cover work surfaces with disposable absorbent mats. Use several layers of containment – trays, polythene sheets, absorbent paper, etc.

SHIELDING OF RADIOACTIVE MATERIALS

When not in use, radioactive sources and stock solutions in the laboratory shall be stored or shielded so that radiation levels in occupied areas will not expose persons unnecessarily.

RADIATION	SHIELDING
Low and intermediate energy beta (H-3, C-14, S-35)	These do not usually present an external radiation hazard and do not require shielding.
High energy beta (P-32, Sr-90)	These should be shielded first with at least ¼" thick Lucite. *
Gamma (I-125, Cr-51)	These should be shielded with lead.

*Lead can then be used, if necessary, to shield any bremsstrahlung x-rays produced in the Lucite.

AEROSOLS, DUSTS, AND GASES

Procedures involving aerosols, dusts, volatile or respirable material must be conducted in hoods or suitable closed systems approved by the RPAC. Where practical, suitable traps should be used to minimise environmental releases.

2.5 Disposal of Waste Generated by the Use of Radioisotopes

Radioactive waste disposal is controlled by the EPA and must comply with the current licence. The licence will state the amounts and types of waste which may be disposed of from the premises. TU Dublin must be able to demonstrate to the EPA Inspectors that the use of radioactive materials is satisfactorily controlled and their disposal carried out safety.

Waste may only be disposed of, if approved, by authorised persons.

Waste arising from the use of unsealed Radioactive sources may only be disposed of by authorised persons in accordance with and in compliance with the conditions in schedule 1, part H and J of the EPA licence (and in compliance with the conditions of S.I. No. 30 of 2019).

Liquid waste must be placed in an appropriate labelled storage container. Such waste must be placed in safe storage until such time as no excess activity is measured.

Solid waste such as contaminated disposable gloves, tissues, disposable pipette tips, etc. must be placed in a designated, marked waste bag and placed in safe storage until no excess activity is measured.

When the waste is no longer deemed to be radioactive and is ready for appropriate disposal all radioactive labels or markings must be removed or defaced. The material may then be disposed as appropriate to the waste type.

2.6 School of Physics, Clinical and Optometric Sciences Standard Operating Procedures for the Use of Sources of Ionising Radiation in Undergraduate Laboratories

The School of Physics, Clinical and Optometric Sciences currently uses a number of sealed sources and an X-ray system in the undergraduate laboratories, the details are provided in Section 1. The sealed sources in use in the undergraduate laboratories are secured in the safe in room CQ-123 on the TU Dublin Central Quad Grangegorman Campus. Monthly visual inspections are carried out and the results held for inspection by EPA representatives. Biennial wipe tests are conducted on all sealed sources and appropriate records of these tests kept by the RPO (City Campus).

UNDERGRADUATE STUDENTS IN PRACTICAL CLASSES IN LABORATORIES CQ-117, CQ-118, CQ-120 and CQ-123

2.6.1 School of Physics, Clinical and Optometric Sciences Standard Operating Procedures for the Use of Sealed Radioactive Sources

1. A limited number of sealed radioactive sources may be used in laboratory classes in rooms CQ-117 (Stage 1), CQ-120 (Stage 1), CQ-118 (Stage 2) and CQ-123 (Radiation/Medical Physics Laboratory), within the School of Physics, Clinical and Optometric Sciences, TU Dublin City Campus, with the approval of the EPA's Office of Radiological Protection and the University's Radiation Protection Advisory Committee who designate the number of sources to be used (See Table 1.1 for list of available sealed sources).
2. Each staff member (full-time or part-time) who is assigned to work in an undergraduate laboratory in which radiation sources are used is required to sign an undertaking that he/she has read the Radiation Safety Manual and is aware of the procedures outlined therein. New staff members (full-time or part-time) will not be assigned to teach in undergraduate laboratories until this requirement is fulfilled. Furthermore, staff members will be required to undertake a mandatory radiation safety course (See Section 6.10).
3. Laboratory sessions in which radiation sources are to be used are to be notified to the Head of School, and to the RPO (City Campus), on or before the Friday of the prior week. The staff member designated as in charge of the laboratory is responsible for this notification.
4. All sealed radioactive sources are stored in a locked Perspex and lead lined fire proof safe located in room CQ-123. The key for this safe is kept in a numerical coded safe in the workshop, room CQ-121. This code will be periodically changed and distributed to the relevant staff.
5. Each laboratory has its own lead box to be used to collect and return the sources to the radiation safe in room CQ-123.
6. The designated staff member in charge of a laboratory session is responsible for taking the required number of sealed sources, in the laboratory's lead box, from the locked safe in room CQ-123 at the start of the laboratory period.

He/she must complete and sign the log-book to indicate the sources which were taken from the safe for the laboratory session (See Table 2.1).

7. Prior to the distribution of the sealed sources the Radiation Warning Sign should be placed on corridor facing side of the laboratory door. Furthermore, the students (not including Stage 1) should read and sign the guidelines for relevant radiation protection information, Appendix A and Section 2.6.2. The staff members in the laboratory are required to ensure that the sealed sources are handled only with the forceps provided for this purpose. The staff member designated as in charge of the laboratory must also ensure that the students sign the laboratory sign-out sheets at the beginning of the laboratory session and then sign the laboratory sign-in sheets when the experiment is completed (see Table 2.2).
8. At the end of the laboratory session the staff member designated as in charge of the laboratory is responsible for ensuring that the sources are restored to the lead box and then returned to the safe in room CQ-123. The logbook is signed to indicate that the designated number of sources have been restored to the safe (see Table 2.1).
9. Following the completion of a laboratory session in which radiation sources are used, the relevant laboratory sign-out/sign-in sheets are to be deposited, by the staff member in charge of the laboratory session, in a designated postbox location (for inspection by the RPO (City Campus)).

   The staff member designated as being in charge of the laboratory session is responsible for ensuring that the relevant sign-out/sign-in sheets are completed.
10. Any staff member must alert the RPO (City Campus) (Jane Torris ext. 5746) to any incident of a radiological nature that has been observed to occur during the laboratory session and to alert the Head of School to any aspect of the operation of the laboratory that he/she feels may hinder the implementation of the radiation safety procedures or otherwise undermine good radiation safety practice.

Table 2.1: LAB CQ-123 Radioactive Source Sign-Out Sheet

To be completed on removing radiation sources from the radiation safe.

	Date	Time	Sources *circle sources being removed from and returned to safe*	Print Name *of staff member*	Signature *of staff member*	Laboratory *in which sources will be used*
Sign-Out of Sources			Am^{241} Co^{60} –1, 2, 3, 4, 5, 6, 7, 8, 9 Cs^{137} – 1, 2, 3 Sr^{90} - 1, 2 Teaching Set T1,T2,T3,T4,T5,T5,T6,T7,T8			
Sign-In of Sources			Am^{241} Co^{60} –1, 2, 3, 4, 5, 6, 7, 8, 9 Cs^{137} – 1, 2, 3 Sr^{90} - 1, 2 Teaching Set T1,T2,T3,T4,T5,T5,T6,T7,T8			

Table 2.2: LOG SHEET FOR THE USE OF SEALED RADIOACTIVE SOURCES IN CLASSES

To be completed during all classes in which radiation sources are used

Class Group:		Room:		Date:		Time of Laboratory Class:	

Source Sign-Out: Signature of Staff Member		Number of sources at beginning of laboratory class:		**Sources** *circle sources in use* Am^{241} Co^{60} –1, 2, 3, 4, 5, 6, 7, 8, 9 Cs^{137} – 1, 2, 3 Sr^{90} - 1, 2 Teaching Set T1,T2,T3,T4,T5,T5,T6,T7,T8
Source Sign-In: Signature of Staff Member		Number of sources at end of laboratory class		
Student Name (Print)	Types of Sources	Label of Source Received	Signature of Student on receiving radiation source	Signature of Student on returning radiation source
	$Co^{60}Cs^{137}Sr^{90}$ Am^{241} Teaching Set			
	Co^{60} Cs^{137} Sr^{90} Am^{241} Teaching Set			
	Co^{60} Cs^{137} Sr^{90} Am^{241} Teaching Set			

2.6.2 Undergraduate Student Laboratory Protection Guidelines

This laboratory uses very low strength radioactive sources. The dose from these sources is negligible, and can be maintained at very low levels by following the guidelines of ALARA and 'Time, Distance, Shielding'. Read the following information and ask your laboratory supervisor to explain any queries you may have before you start the experiment. Further information relating to radiation safety can also be found at http://www.dit.ie/healthsafety/radiationprotection/
You must sign the bottom of the sheet stating that you have understood the information it contains before starting the experiment.

If you are pregnant or breastfeeding an information leaflet (see Appendix D) is available for consultation in the laboratory, please consult the person in charge regarding this.

The Concepts of ALARA and Time, Distance and Shielding

Radiation protection of any individual (who is not a hospital patient) is based upon the ALARA principle, which says that the amount of dose to the person must be kept:

As
Low
As is
Reasonably
Achievable

The means by which this is done in practice is to ensure that:

1. The time spent exposed to the source is kept as low as possible. Since radioactive materials decay radioactively with a rate of decay specified by their half-lives, the smaller the time spent in the presence of the source the smaller the number of alpha, beta or gamma particles (exposure) which will be incident on the person, and the smaller the dose that will be received from the source regardless of the type of source. In practice, if it is necessary to be close to the source at any time, do so for as short a time as possible;

2. The distance between the person and the source is kept as high as possible. The number of alpha, beta or gamma particles that hit any point at distance from a radioactive source decreases with the square of the distance from the source (inverse square law) per unit time. Therefore, if one doubles the distance from the source to any point in space, the number of alpha, beta or gamma particles hitting that point will be quartered, and so the dose received will be quartered. As a rule of thumb for low-level sources, if one stands a distance of 2 meters from the source, the dose will be very small. In practice stay as far away from the source as is possible;

3. Shielding is used to limit the number of alpha, beta or gamma particles that exit the source. Materials with high atomic number (e.g. lead) stop alpha, beta or gamma particles easily and reduce the exposure to negligible levels. In practice, 3 mm of lead is usually sufficient to bring the dose from any radioactive emission down to very small levels. In this lab we use 2.5cm lead blocks, which is a very high level of shielding, and reduces the exposure to a very low level;

I certify that I have read and understood the above information.

Signed:_____ Date:_____

2.6.3 Standard Operating Procedures for the X-ray Didactic Apparatus

X-ray Tube: Molybdenum (Mo): (Anode voltage range: 0 – 35kV, Emission Current range: 0 – 1mA)

1. The Didactic X-ray apparatus must only be operated by individuals who have read the Didactic X-ray safety manual and who have read and understand the procedures in this document.
2. Ensure that usage of the X-ray machine has been noted in the log book.
3. Verify that the “X-ray in use” warning signs are visible and unobstructed.
4. Before using the X-ray machine, inspect the machine to ensure it is not damaged, particularly the lead glass panes and sliding doors as well as the lead glass tube surrounding the X-ray tube, the following is a photograph (Figure 1) of how the system should appear.

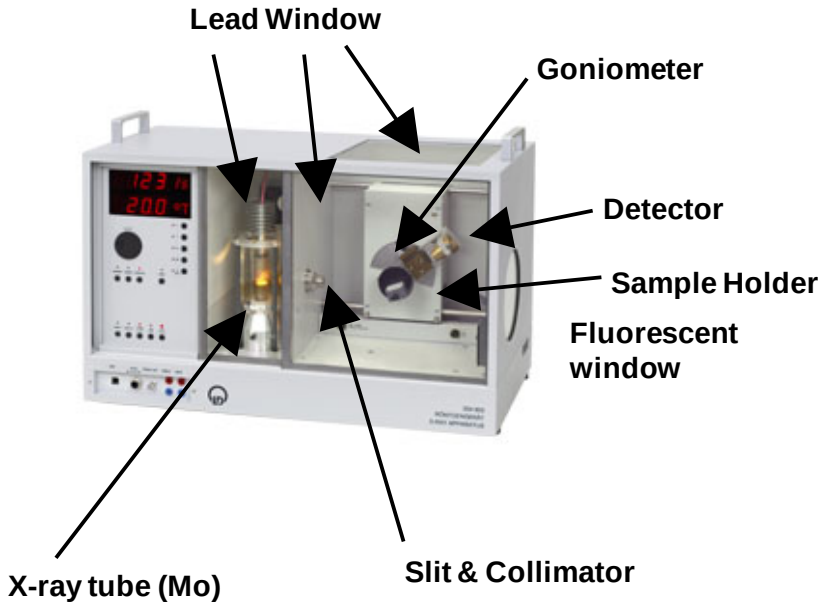


Figure 1: Photograph of the Didactic X-ray machine with main components

5. **If any damage/faults are observed this should be reported immediately** to the staff member in charge of the laboratory. A sign indicating that the system should not be used will be put in place by the staff member in charge.
6. Never interfere with any part of the apparatus.
7. Do not remove the lead glass from the x-ray tube chamber and never attempt to loosen the mounting screws.
8. Ensure the fans at the back and sides of the machine are not blocked so that they can operate and prevent the anode from overheating.
9. The goniometer is positioned solely by electric stepper motors – Do not block the target arm and sensor arm of the goniometer and do not use force to move them.
10. All repairs and maintenance may only be carried out by the manufacturer, LD Didactic GmbH. The only exceptions are the replacement of the X-ray tube and any height adjustments of screws which are possible through holes in the bottom plate and are provided by the manufacturer for this purpose.
11. In order to produce X-rays the apparatus door must close correctly. The machines interlock system will prevent X-rays from being produced if the door is not properly closed.
12. Do not use the machine if the warning display does not flash “SAFE OK” to indicate that the door is correctly closed.
13. Use either the machine-specific Leybold Physics Leaflets or the dedicated School of Physics, Clinical and Optometric Sciences experimental procedures when using this system. Furthermore, follow the Safety notes, Set up Guidelines and Procedure for the experiment.
14. To record data using computer software; open “X-ray apparatus” icon on the desktop and follow the procedures as described in the machine specific Leybold leaflets or School of Physics experimental procedures.
15. Use the X-ray apparatus for required tests.
16. Reposition the objects or remove the crystals only when the system is turned OFF.
17. At the end of the experiment, power off the X – ray machine at the side of the X-ray machine and at the power supply at the wall socket, and also shut down the data recording computer.
18. Attach the cover to protect the luminescent coating of the fluorescent screen from ambient light.

2.6.4 School of Physics, Clinical and Optometric Sciences Standard Operating Procedures for Use of Sources of Ionising Radiation in Undergraduate Laboratories for Project Work in Room CQ-123

Where an individual student is engaged in an undergraduate project involving the use of sources of Ionising Radiation, she/he must sign the declaration that she/he has read and is aware of the contents of the regulations to be observed by students in relation to the use of radioactive materials in room CQ-123 which is given in section 2.6.2, and agrees to carry out their work in accordance with the regulations.

- Each such student must use the appropriate Personal Protective Equipment as deemed necessary after consultation with the RPO (City Campus).

Students are allowed to work in these rooms during normal working hours, provided the supervising lecturer ensures his/her safe conduct and that he/she follows the guidance of the technical officer.

The supervising member of authorised staff is responsible for opening the room and any other facilities within the room at the start of the work period and for ensuring that it is locked up at the end of the work period.

The supervising member of authorised staff must ensure that the student is monitored appropriately as per the specific Standard Operating Procedure which was developed in consultation with the RPO (City Campus) prior to the start of the project.

The supervising member of authorised staff must ensure the completion of the log book at the start and end of the work and also fulfil any other safety requirements and checks as deemed necessary by the RPO (City Campus).

2.7 CREST XRD Standard Operating Procedure

Operation of X-Ray Diffraction-Rigaku Miniflex

2.7.1.1 Title

Standard Operating Procedure for the operation of the Rigaku Miniflex Benchtop X-Ray Diffractometer (XRD).

2.7.1.2 Purpose

This SOP consists of the operating procedure for the Rigaku Miniflex Benchtop X-Ray Diffractometer (XRD).

2.7.1.3 Scope

This document is the standard procedure for the operation of the Rigaku Miniflex Benchtop X-Ray Diffractometer (XRD) maintained by CREST and located in room B.09.0 of the FOCAS Research Institute. It is to be used in conjunction with the operating manual. A printed copy of the instrument manual supplied by the manufacturers is located beside the XRD machine and a soft copy is saved onto the desktop of the instrument PC.

2.7.1.4 Related Procedures

Procedure	SOP Number
Use of Personal Protective Equipment at CREST	50-001
Risk Assessment and MSDS Storage	50-002
Completion and control of Controlled Documents and Records	05-001
Training & Competence of CREST Employees	18-001
Radiation Safety Manual 2023	N/A
TU Dublin Radiation Protection Note for Pregnant Workers	N/A
TU Dublin Staff Radiation Awareness Policy	N/A

2.7.1.5 Definitions

XRD	The Rigaku Miniflex Benchtop X-Ray Diffractometer (XRD) is located in room B.09.0 of the FOCAS Research Institute.
XRD Keyholder	The designated person responsible for the control of the XRD Key will approve the use of the XRD. The XRD Instrument key is kept in the CREST Office. Use of the XRD is now done through the FOCAS Bookit system and must be completed a week in advance.
XRD Authorised Personnel	Authorised personnel have completed the TU Dublin Radiation Protection course and are fully trained in the use of the instrument. The list of approved XRD users is at CREST TEAMS I Drive Quality\Health and Safety\Radiation Information, this is updated annually.
Room Keyholder	A copy of the Room key is held in the CREST Office, Cabinet 1. Upon change of key holder, the RPO (City Campus) will be informed and this SOP will be amended. While the instrument is not in use, the XRD room will remain unlocked. T**he room will remain locked while the XRD instrument is in use** T**he room will remain locked while the XRD instrument is in use**
RPO/DRPO: The Radiation Protection Officer/Deputy Radiation Protection Officer.	The Radiation Protection Officer for the TU Dublin City Campus is Jane Torris, School of Physics, Clinical and Optometric Sciences (Tel: 01-2205746 and email: Jane Torris@tudublin.ie) The Deputy Radiation Protection Officer for the TU Dublin City Csmpus is Dr Cathal Flynn, School of Physics, Clinical & Optometric Sciences (Tel: 01-2205716 and email: cathal.flynn@tudublin.ie).
The Radiation Protection Supervisor (RPS)	The RPS for CREST is Maura Duffy email:maura.duffy@tudublin.ie. Tel 01-220 6941 Upon change of the RPS, the RPO (City Campus) will be informed and this SOP will be amended.

Local Rules	The current version (at the time of use of the present SOP) of the TU Dublin Local Rules governing the use of radiation on the campus of the Technological University Dublin is found online in the Radiation Safety Manual (Cf 4.0). The relevant sections of this document (i.e. the present SOP and the XRD Safety Guide) must have been read and signed by any individual using the present SOP before using the XRD.
Logbook	Logbook-QR code on the front of the machine in which details of the use of the XRD are recorded
Training Videos	Videos recorded during the online training session, stored on the XRD PC.

2.7.2 Responsibility

1. Only authorised personnel may use the instrument.
2. The user must have completed the TU Dublin Radiation Safety Training. This is a 1-day training course and must be refreshed every 3 years.
3. Users must update the logbook when using the XRD.
4. Any issues must also be recorded into the log-book and the equipment owner/RPS must be contacted about the issue.
5. A monthly safety check must be completed by the CREST RPS/authorised user and recorded in the log book.

2.7.3 Training Requirements for this SOP

Personnel Training Required	Yes	No
CREST Management Staff that require ongoing XRD usage	X	
CREST/TU Dublin Research Staff that require ongoing XRD usage	X	
CREST/TU Dublin Research Postgraduate Students that require ongoing XRD usage	X	

2.7.4 Safety

1. Only Authorised Users may use the XRD.
2. The Miniflex X-Ray Diffractometer produces ionising radiation using high voltage sources. Care must be taken to ensure the safety both of the operator of the diffractometer and nearby researchers.
3. Only the XRD operator may be present in Room B.09.0 while the XRD is in operation. The room must be locked from the outside when the unit is in operation and the operator is not present within the room.
4. Use of the XRD must be scheduled using the FOCAS Bookit system.
5. If any known, or potential, safety risk is associated with the XRD samples, a relevant Risk Assessment & MSDS must be provided in advance of the analysis taking place.
6. A safety survey is carried out by the CREST RPS, or a trained member of staff, on a monthly basis to ensure that the XRD is in good working order and there is no radiation leakage. The RadEye B20 multipurpose survey meter will be used to measure radiation.
7. Malfunctions of the instrument observed must be reported immediately to the RPS and the RPO (City Campus)/DRPO (City Campus),Turn off the XRD immediately.
8. The user must read the current RADIOLOGICAL SAFETY MANUAL, the TU Dublin Staff Radiation Awareness Policy (Cf 4.0) and if necessary the TU Dublin Radiation Protection Note for Pregnant Workers (Cf 4.0)

2.7.5 Materials/Equipment

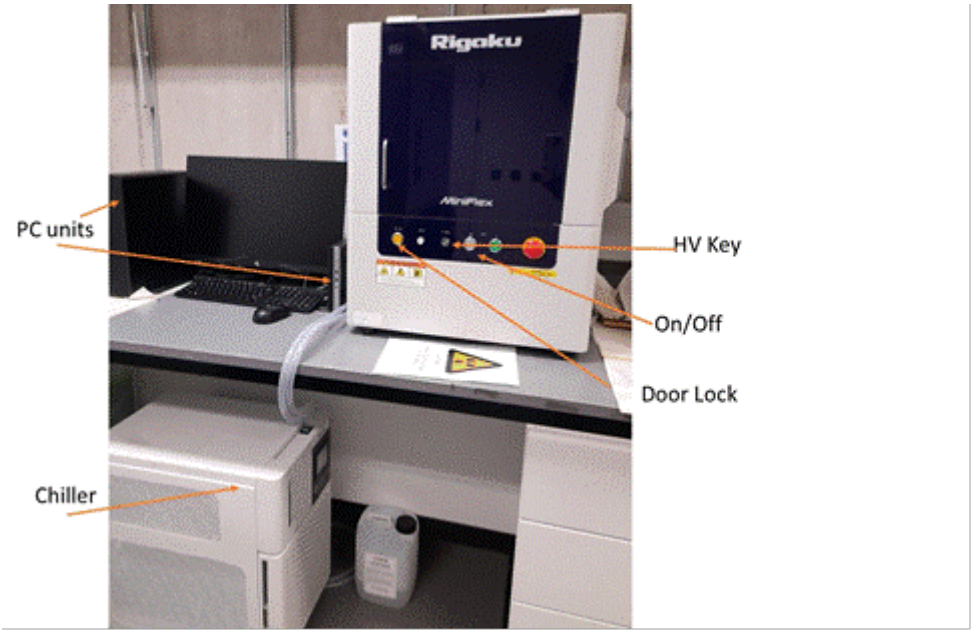


Figure No. 1 Rigaku MiniFlex X-Ray Diffraction (XRD) instrument located in Room B.9.0 of the FOCAS Research Institute

2.7.6. Procedure

1. Obtain the HV enable key and door key to room B.09.0 from the key holder.
2. Place the X-Ray in Usage sign on the door of room B.09.0.
3. The door must be locked if you leave the room during operation of the XRD
4. The XRD is operated as detailed below
5. Turn on the chiller and ensure that water is flowing to the XRD, as the unit will not work until the chiller is cool. Turn on at least 15 minutes before use. The chiller is located below the workbench as shown in Figure No.1
6. Insert the HV Enable key to the display panel on the front of the main body
7. Turn on the PCs, control PC and small detector PC (Elitedesk)
8. Turn on the Power circuit breaker at the rear (LHS) of the MiniFlex600 main unit (switch up is on), then, press the Green Power ON button at the front of the instrument.
9. Click open the Smartlab Studio II software on the PC.
10. Press in and turn on the HV Enable Key clockwise. Whilst in the XRD Measurement plugin, click <H/W Status> on the software. There are other windows which may show up including data browser. XG control, optics management, startup/shutdown and corrections as shown in Figure No. 2 – these can be minimised and used as required.

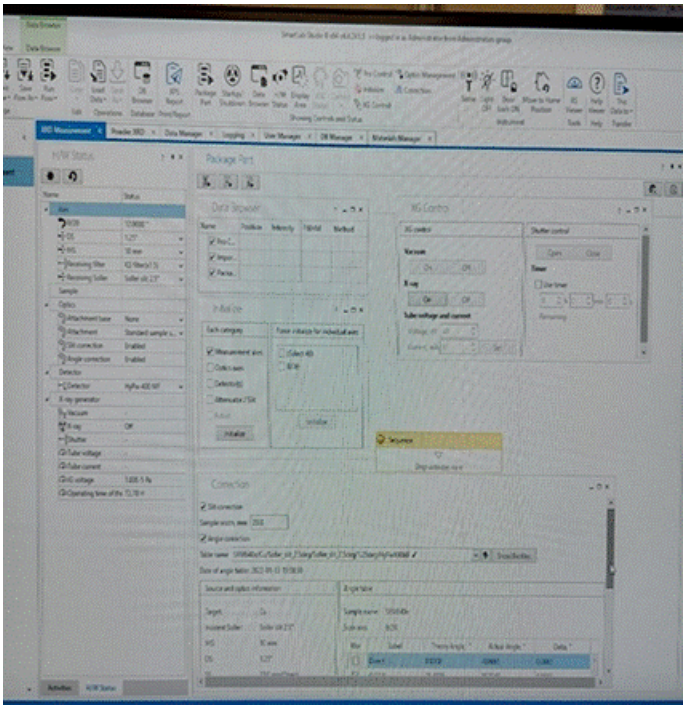


Figure No. 2 XRD Measurement section.

11. Click <Startup/Shutdown> window
12. Click Run and click Yes to run startup. This may take up to 10 minutes to complete.
13. Once the aging conditioning has been completed, the XG control panel will show that the X-ray is on, as in Figure No. 3.

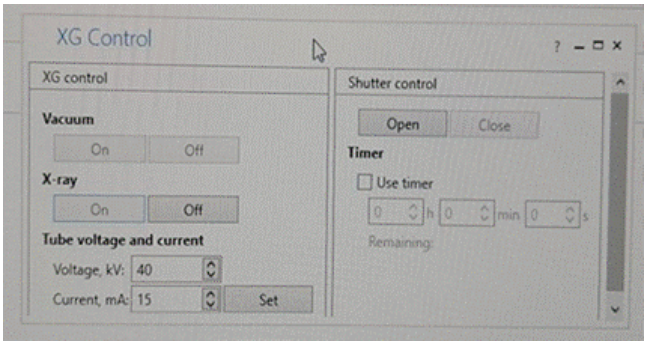


Figure No. 3 XG Control showing X-ray and shutter control conditions.

14. Click the set button.
15. The XRD will ramp up to the required voltage and current. Check in the HW status window open on the LHS of the screen (Tube Voltage 40kV and Tube Current 15mA)
16. Check that the X-Ray warning lights are on, on top of the XRD instrument.

2.7.7 Sample Preparation

NOTE: Do not touch the keyboard/PC/door of instrument with gloved hands.

NOTE: Metal spatulas or anything that will scratch the sample holder must not be used. All care must be taken to keep powder from leaving the samples holder while in the instrument.

NOTE: Solvent can only be used to wipe down the holders on a Kim wipe.

NOTE: You MUST return at the end of your runs to clean off the sample holders before the next user.

1 The glass slide sample holder has an indented section which prevents the sample from dropping from the holder, as shown in Figure no.4.

2 Grind the sample, with a mortar and pestle, to a fine powder if required.

3 Add the sample to the indented section of the glass holder.

4 Spread/flatten the sample using another glass slide to evenly distribute the sample over the indented area.

5 This also ensures that the sample holder surface is aligned with the sample measurement surface.

6 If the sample is misaligned with the sample holder surface, it will result in angle deviation.

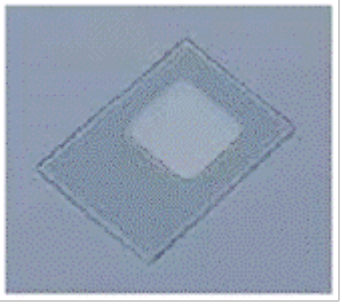


Figure No.4 The glass slide sample holder

7 If the sample amount is insufficient or if it does not stay in place, it is possible to apply a thin coat of binder on the on the back side of the glass sample holder, then sprinkle the sample on the binder-coated area and shake off the excess sample.

8 However, halo from the glass or binder can be observed if the attached sample is uneven. Therefore, this cannot be used for quantitative measurements but provides sufficient data for qualitative analysis.

A **smear mount method** has also been utilised for inorganic substances:

9 In this method, a sample is mixed with a small amount of a volatile organic solution such as alcohol and acetone.
10 It is then grounded thoroughly with a mortar and pestle.
11 A thin coat of this sample is applied to the glass sample holder.
12 If there is only a small amount of sample, the intensity of the diffracted X-rays will appear lower in the high-angle area, which reduces the reliability of the result.

2.7.8. Mounting the sample holder onto the stage

1. Under the shutter control section on the screen, select close.
2. Press the door lock button on the front of the instrument. When a steady set of tones are heard open the door.
3. Place the sample holder with the sample into the area just above the clips, place the side which does not have the indented section for the sample towards the back with the sample facing the analyst.
4. Gently push the sample holder forward until it hits the back of the goniometer, as shown in Figure no. 5.
5. The sample is secure, close the door and then press door lock button.

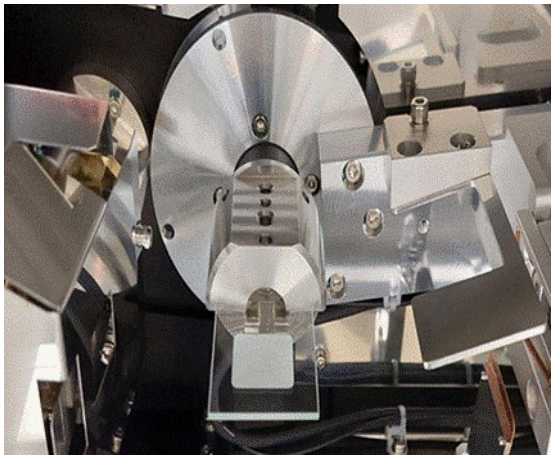


Figure No. 5 Sample holder with sample in the correct position

2.7.9 How to set up the programme to perform measurements with SmartLab Studio II:

1 Once the sample holder containing the sample has been placed on the stage, click the Package Part icon at the top of screen.
2 Make sure you are in the XRD Measurement Plugin. This can be assessed by clicking the tab named XRD measurement.
3 Make sure you are in the XRD Measurement Plugin. This can be accessed by clicking the tab named XRD measurement.
4 If that is not showing, click the plugins bar on the far LHS of the screen and a window should pop up that has XRD Measurement on it. The tab should show up after you click it.
5 The screen gives access to various activities (measurement, alignment, utility, command, analysis and administrator).
6 A sequence is present to which the general measurement must be added.
7 Double click on the General Measurement on the RHS and general measurement is added to the sequence.

8 Click this general measurement which has just shown up and a dialogue box consisting of 4 groups appears. These include, Optical conditions, Measurement conditions, Saved measured data and options. These 4 group setting panels can be expanded or collapsed by clicking on the up/down arrow.

Set up the following conditions:

9 **In the optical conditions group:**

X-Ray 40kV and 15 mA (this would have been set up earlier; these ensures that the X-ray tube is run at its maximum power.) Click on the down arrow to expand the optical conditions.

Slit system: select variable + Fixed slit system

NOTE:

- The variable slit system enables performing a measurement with the constant irradiation.

  Width of 20 mm at the range $2\Phi = 2^{O}$ to 67^{O}. X-ray is irradiated on a measurement while changing the size of the divergence slit along with the sample size 20 mm. The divergence angle of the incidence X-ray can be broadened up to a maximum of 4.2^{O}. A measurement that exceeds $2\Phi = 67^{O}$ cannot be performed due to the angle exceeding the limit. Therefore, use of the variable + fixed slit system is required.

  For the variable + fixed slit system, if only the fixed slit is used, the X-ray is irradiated outside of the sample at low angle side. Combining a variable slit so that the X-ray radiation width becomes the same width 20 mm at the low angle side. Therefore, the variable + fixed slit system can be used for low angle area and high angle area within the measurement range $2\Phi = 2^{O}$ to 145^{O} respectively in a measurement. By using slit correction, the intensity of the variable slit used at the low angle side can be corrected to the intensity of the fixed slit.

  Incident Soller: select Soller slit 2.5^{O} from the dropdown menu

  IHS: select 10mm from the dropdown menu

  DS: select 1.25^{O} from the dropdown menu

  Divergence slit: Controls the irradiated length of the X-Ray beam on the sample.

  Slit size depends on sample size and starting scan angle.

  SS: select 13.0mm (open) from the dropdown menu

  Soller Slit: Prevents axial divergence and improves peak shape and symmetry.

- Resolution of the peaks can be improved by narrowing the width of the soller slit. In general, to obtain a very narrow peak reduce the horizontal and axial divergence, therefore a relatively narrow divergence slit and soller slit must be used.
  Receiving Soller: select soller slit 2.5^{O} from the dropdown menu
- Decreasing the width of the standard receiving soller slit achieves higher resolution.
  RS: select 13.0mm (open) from the dropdown menu.
- Receiving slit: Increasing the width of the receiving slit generally increases the peak height and width but decreases the ability to resolve peaks.
  Monochromatization: select KB filter (x1.5) from the dropdown menu.

10 In the Measurements conditions group:

Scan axis: $\Phi/2\Phi$
Scan mode: 1D (scan)
Tick the box under Exec.
File Path: this is the link to where the data will be saved.
e.g. if a folder has been created with the analyst name under documents, then the link will be C:\Users\User1\OneDrive - Technological University Dublin\Documents\Analyst name
File name: Give this your sample name followed by the date e.g. Sample Number 1 220217 (220217 implies year 2022, month February 02, day 17)
$Start^{O}$: 3.0000^{O} $Stop^{O}$: 90.0000^{O} $Step^{O}$: 0.0100^{O}
Speed (^{O}/min): 10.0
(To increase the S/N ratio, decrease the speed (^{O}/min). Select set.

11 In the Saved Measurement data group:

Tick the Saved Measurement data box.

12 In the options group:

Tick the box for Show optical devices confirmation message.
Tick the box for Move to home position after measurement.
At the bottom of the screen the calculated scan duration is given in hr, min and sec.

1. Click ok.
2. Click the Home tab at the top of the screen.
3. Click the Run Flow icon and click on the run flow on the ribbon.
4. Press Run
5. Upon completion of the run, a pop up appears-flow sequence completed-click ok.

13 Completion of sample analysis:

1. Press the door lock button in front of the instrument.
2. Open the door.
3. Gently pull out the sample holder.
4. Recover the sample and place inside the appropriate sample container or dispose of as appropriate
5. Clean the glass sample holder with kim wipe and either water or isopropanol.

14 Data analysis:

1. Click on the Powder XRD tab.
2. Set up the following under Flow bar:
   2.1 Select file system
   2.2 Task: Basic
   2.3 Working mode: New Project
   2.4 Dataset: Simulation
3. Peak Evaluation on the LHS of the screen should be highlighted already with a green dot. If there is no LHS panel shown on the LHS of the screen (i.e. the flow bar), then go to the view tab and select reset tree and view layout.
4. Click load data.
5. Select the file which you have run
6. Select open
7. This will load up a diffractogram and a table with information, as shown in Figure no.6.

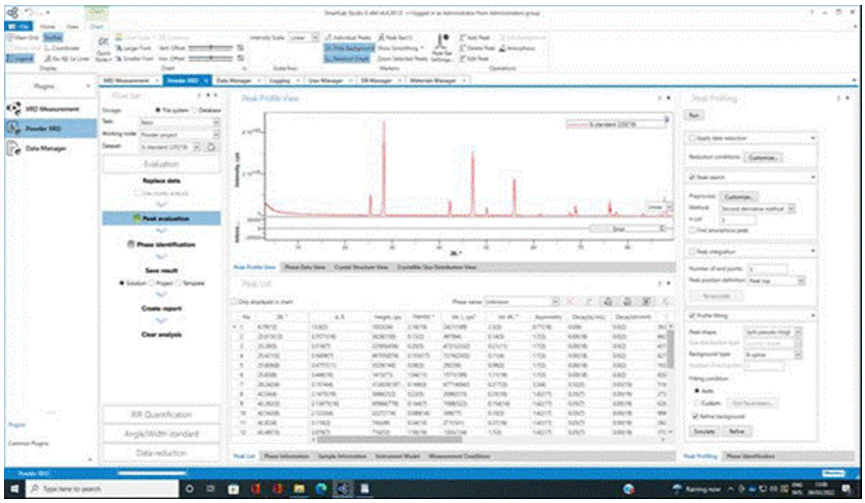


Figure No.6 Diffractogram and table from a test run.

(As peak evaluation was highlighted already in green, this automatically will load up the diffractogram and the table.) Information obtained is based on the diffractogram. The table provides information such as:

- the number of peaks present
- 2Φ, the peak position.
- Intensity of the peaks etc.

8. Click on the diffractogram plot and by selecting the peak bar setting tab it is possible to select the maximum of a given peak.
9. Once selected, a pop up for peak bar settings will show:
    9.1 Label setting - tick beside show peak labels
    9.2 Bar settings - tick beside show peak bars
    9.3 Click apply and close.
10. On the RHS of the screen Peak profiling section needs to be filled in, shown in Figure no.7.
11. Tick the peak search. Method: Second Derivative method peak.
12. Preprocess: customise.
13. σ cut: 3. Peak Integration: no. of points 3
14. Peak position definition: peak top. Tick profile fitting.
15. For peak shape: split pseudo-voight.
16. For background type: B-spline.
17. Select Auto.
18. Tick refine background.
19. Click refine.
20. Click Phase Identification on the LHS and then on the RHS of the screen, go to Phase Identification as shown in figure no. 8.

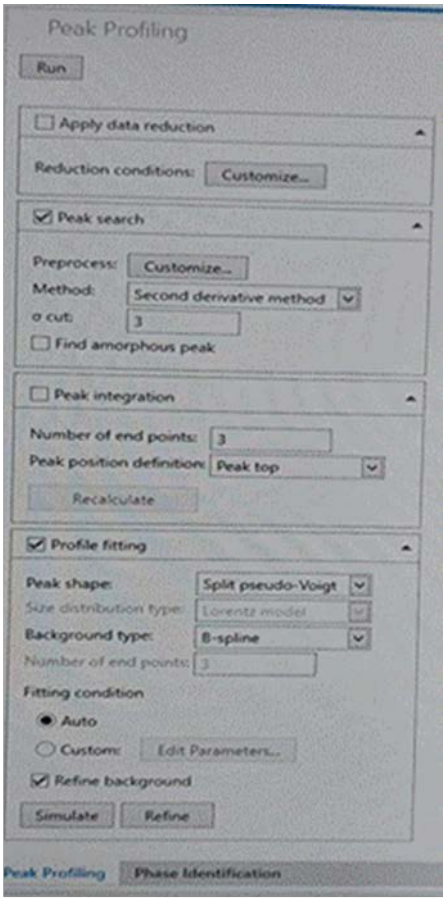


Figure no. 7 Peak profiling requirements

21. Select import.
22. Select d-I database from the drop-down arrow.
23. In the pop-up tick COD and tick Rigaku Demo 2018, see Figure no.9.
24. Fill in any other information available:
25. Phase name – e.g. Silicon (type in full name for a narrower search).
26. Chemical formula – Si.
27. Elements – it is possible to select a variety of elements. It is possible to select 4 headings:
    unknown, not included, included and include one at least.
28. Stoichiometry.
29. Crystal system – e.g hexagonal. Space group. DB Card number.
30. Select search

Based on information provided a number of files are shown giving an indication as to what your sample may be as shown

31. To compare these files, click the file name of interest
32. Select add and then select close. These files will appear under Phase Identification, search results on the RHS of the screen – see figure no.10.
33. Tick optimise diffraction pattern.
34. Highlight the file.
35. Click the downward arrow.

36. This file has now been transferred to the candidate phase as shown in figure no.11.
37. Click the downward arrow again if two files are going to be compared with your sample and then click set.

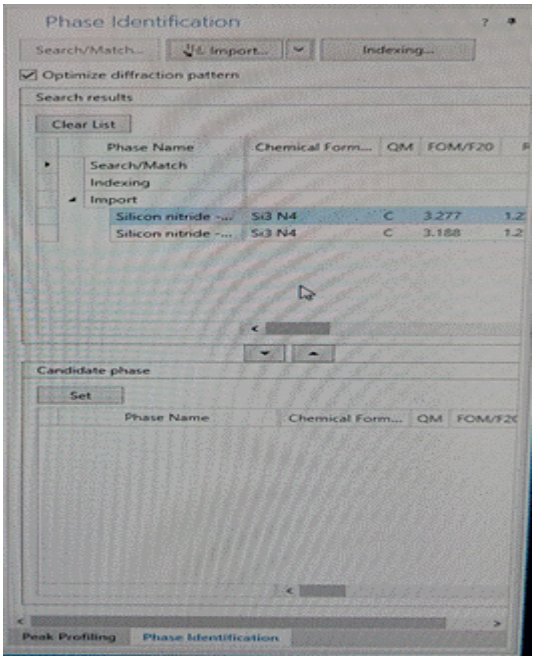


Figure no.10 Phase Identification section

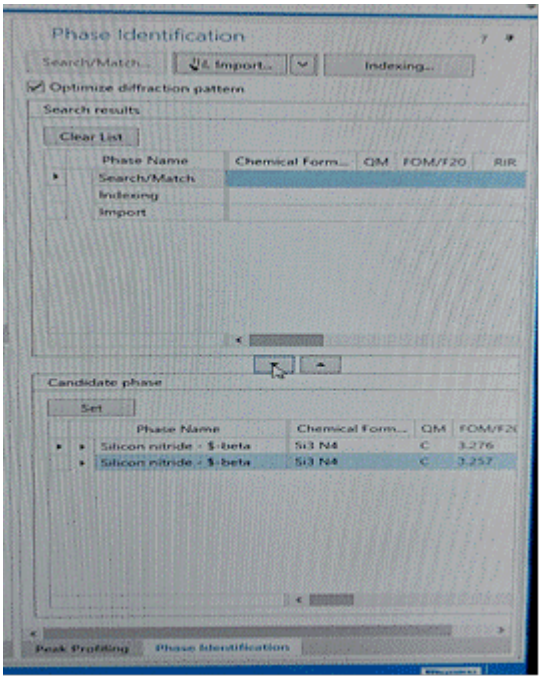


Figure no. 11 Candidate Phase section

This will overlay the file/s you have selected with the sample which has been run. Compare the peak positions to see if they overlay with each other.
Qualitative information is obtained from the peak position i.e. the 2Φaxis.

15 To save the results:

1. Click on save result on the LHS as either solution, project or template.
   - 1.1 File name:
   - 1.2 Save as type: Rigaku MR solutions (.rmrsln)
2. Press save

16 To transfer the date generated for the sample to excel:

1. Right click anywhere on the diffractogram plot.
2. Select export as shown in Figure no.12
3. Select export data.
4. In the pop up, as shown in Figure no. 13a, 13b and 14 fill in the following information:
5. In the selection tab: Tick select all and Tick the name of your sample file saved.
6. In the format tab: File text: Text
   Encoding: Unicode (UTF-
   Delimiter: TAB

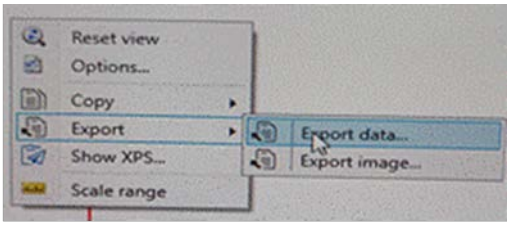


Figure no.12 Exporting the data to Excel.

7. Select Export as shown in Figure no.14: File name: select the file you ran
   Save as type: Text files (*.txt)
   Select save

Figure no. 13a Selection tab

Figure no. 13b Format tab

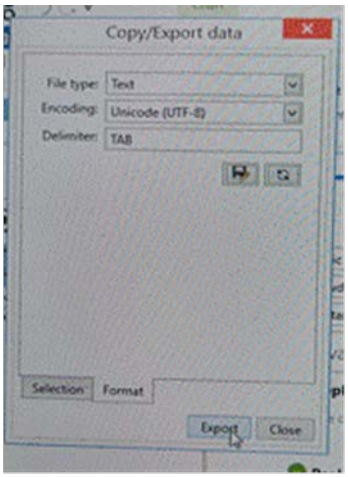


Figure no. 14 Select export

The data generated can be copied and pasted into an Excel worksheet and plotted as required.

17 To create a report:

1. Click create report on the LHS.
2. In the pop-up, click the sections required.
3. Press ok. The report is generated.

18 Some other useful tabs include:

- Vertical and horizontal offset which allow the movement of overlaid diffractograms vertically and horizontally.
- Residual graph – usually active.
- Hide background.
- Show smoothing – try to avoid using this as it will lead to biased results.
- Edit peak – if there is a shoulder on a peak it is possible to remove the shoulder by highlighting the peak and moving it to one side: then by dragging the cursor up or down it will make the peak bigger or smaller, removing the shoulder.
- Toolbar should always be active.
- Coordinate should be clicked – it will allow you to obtain x and y coordinates of the peak when the curser is hovered over the peak.

2.7.10 Instrument shutdown:

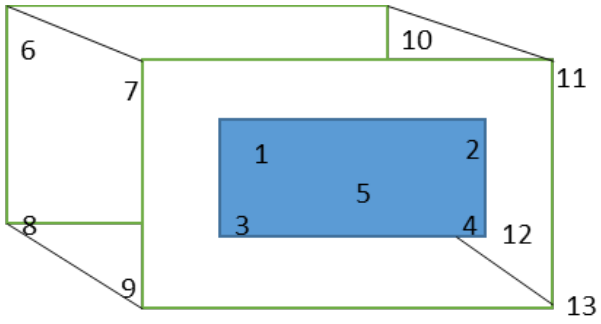
1. Once the sample/s has/have been run, shut down the XRD as follows:
2. Confirm that the x-ray generation has stopped; on the XG control panel in SmartLAb II, click XG control-X-ray OFF button.
3. The X-Ray warning lights on the instrument will turn off.
4. End the Smartlab II on the control PC.
5. Press the Power OFF button on the front of the XRD.
6. Turn off the power switch at the back of the XRD, switch down when off.
7. Remove the HV enable key.
8. Turn off the chiller unit once the x-ray generation has been stopped for at least 3 minutes
9. Switch off the HyPix Server beside the instrument. The power on the PC automatically turns off.
10. Remove the sign from outside the door and fill in the logbook as appropriate.

2.7.11 Monthly Safety Check and Radiation Survey

1. A radiation survey is completed monthly to ensure that there is no radiation leakage from the XRD unit by the designated key holder using the RadEye B20 multipurpose survey meter.
2. Place the X-Ray “In Use” sign on the door. Lock the door if you leave the room while the XRD is in operation.
3. Record all results in the XRD Safety Survey Logbook - scan in the barcode which is on the RadEye 20 multipurpose survey meter box and fill in as appropriate.
4. Turn on the chiller and leave for approx. 15 minutes, turn on the XRD as detailsed above
5. <u>Chiller Check:</u>
   Confirm the cooling water is flowing into the Miniflex main body from the chiller. (Check the pipe by touch)
6. X-Ray <u>Warning Light Check:</u>
   - On the control panel in SmartLab II click XG control <X-ray ON> button. The X-Ray warning lights will turn on.
   - On the control panel in SmartLab II click XG control <X-ray OFF> button. The X-Ray warning lights will turn off.
7. <u>X-ray shutter and door lock Check:</u>
   - Press the Door Lock Button on the front of the XRD. Open the door: The x-ray shutter closes and the door unlocks. The Door Open button will blink.
   - On the control panel in SmartLab II click XG control <Shutter Open> button, the door will not open.
   - On the control panel in SmartLab II click XG control <Shutter Closed> button, the door will open.

8. Radiation Leakage Check

1 Measure the background radiation in the middle of the room.



2 The leakage radiation is measured at the 13 positions listed below with the XRD set to 40KV$_p$, 15mA and the shutter opened.

3 Place the probe of the RadEye B20 monitor at each location for 30s to 60s.

4 Record the radiation level; it should be approximately the same as the background.

5 If a measurement of >1microS/hr is received, turn off the unit immediately and contact the RPO (City Campus)/DRPO (City Campus).

6 The unit may not be used again until it has been passed as safe by the RPO (City Campus).

Amendment Record

Section	Reason for Revision	Date	Revision
All	This is a new procedure	11/03/2022	B
10	Remove the need to book through the FOCAS Bookit system	11/03/2022	
11	Sample preparation	11/03/2022	
12	Mounting the sample holder onto the stage	11/03/2022	
13	How to set up the programme to perform measurements with SmartLab Studio II	11/03/2022	
14	Completion of sample analysis	11/03/2022	
15	Data Analysis	11/03/2022	
16	How to save the results	11/03/2022	
17	How to transfer the data to Excel	11/03/2022	
18	How to create a report	11/03/2022	
19	Other useful tabs	11/03/2022	
20	Instrument shutdown	11/03/2022	
21	Monthly safety check and radiation survey	11/03/2022	

Appendices

Appendix (i) *Questionnaire for SOP (11-005).*

Circulate electronically to all CREST staff on the training list. All completed training questionnaires are saved in the SOP Training Folder of the relevant SOP on the I:\Quality\Controlled Documents\SOP\Current SOP\SOP XX-XXX\SOP XXX-XXX Training.

Questionnaire for SOP 11-005

Q1. Who are authorised xrd users?
Q2. How is use of the xrd scheduled?
Q3. Briefly list the steps to turn on the xrd.
Q4 Briefly list the steps to turn off the xrd.
Q5. Where is the xrd manual located?
Q6. What is the radiation survey and who carries it out?

The trainee and trainer hereby confirm that the trainee:

- *has read and understood this SOP; and*
- *agrees to carry out related actions according to the instructions in this SOP.*

	NAME,TITLE (PRINT CLEARLY)	**SIGNATURE**	**DATE**
TRAINEE:			
REVIEWED BY (TRAINER):			

2.8 CREST XRF Standard Operating Procedure

Operation of X-RAY FLUORESCENCE (XRF)

2.8.1.1 Title

Operation of the hand held X-ray Fluorescence unit in CREST.

2.8.1.2 Purpose

The purpose of this procedure is to describe the operation of the hand held and mobile testing equipment capable of X-Ray Fluorescence, XRF.

2.8.1.3 Scope

This document is the standard procedure for the operation of the hand held XRF maintained by CREST and located in room B.18.0 (Consultancy Laboratory) of the FOCAS Research Institute, TU Dublin, Camden Row. It is not designed to replace the manual. The equipment manual is located on the XRF Laptop and inside the accessories case.

2.8.1.4 Related Procedures

Procedure	SOP Number
Use of Personal Protective Equipment at CREST	**50-001**
Risk Assessment and MSDS Storage	**50-002**
Completion and control of Controlled Documents and Records	**05-001**
Training & Competence of CREST Employees	**18-001**
Radiation Safety Manual 2023	**N/A**
TU Dublin Radiation Protection Note for Pregnant Workers	**N/A**
TU Dublin Staff Radiation Awareness Policy	**N/A**

2.8.1.5 Definitions

MSDS	Material Safety Data Sheet
TU Dublin	Technological University Dublin
RPO/DRPO/RPS: The Radiation Protection Officer/Deputy Radiation Protection Officer/radiation Protection Supervisor.	RPO (City Campus): Jane Torris, The School of Physics, Clinical and Optometric Sciences (Tel: 01-2205746 and email: Jane Torris@tudublin.ie) DPRO (City Campus): Dr Cathal Flynn, The School of Physics, Clinical and Optometric Sciences (Tel: 01-2205716 and email: cathal.flynn@tudublin.ie) RPS: Maura Duffy (email maura.duffy@tudublin.ie)
CREST RPS	The RPS will approve the use of the XRF, this must be scheduled in advance through the CREST equipment scheduling procedure. Only competent, trained persons will be authorised to use the XRF.
Local Rules	The current version (at the time of use of the present SOP) of the TU Dublin Local Rules governing the use of radiation on the campus of the Technological University Dublin is found online in the Radiation Safety Manual (Cf 4.0). The relevant sections of this document (i.e. the present SOP and the XRF Safety Guide) must have been read and signed by any individual using the present SOP before using the XRF.
Logbook	Details of the use of the XRF are recorded in the log-book.
List of trained users	A trained user is one who has received full training on the operation of the instrument, along with the TU Dublin Radiation Safety Training. The current list of trained user is available at the following link I:\Quality\Health and Safety\Radiation Information\Radiation Protection Personnel List

2.8.2 Responsibility

1. Only properly trained personnel may use the instrument.
2. The user must have completed the TU Dublin Radiation Safety Training. This is a 1-day training course and must be refreshed every 3 years.

3. Users must update the logbook when using the XRF and for each sample analysed.
4. Any issues must also be recorded into the log-book and the equipment owner/RPS must be contacted about the issue.
5. A monthly safety check must be completed by the CREST RPS/trained user and recorded.

2.8.3 Training Requirements for this SOP

Personnel Training Required	Yes	No
CREST Management Staff that use the XRF	X	
CREST/TU Dublin Research Staff that use the XRF	X	

2.8.4 Safety

1. The XRF may only be used by trained personnel.
2. The XRF is stored in a locked Radiation Safe in Room B.18.0 in the FOCAS Research Institute. Warning signage is placed on the door of B.18.0 during use.
3. The XRF may not be removed from B.18.0 without approval from the RPO (City Campus)/RPS.
4. Use of the XRF must be scheduled with the CREST RPS.
5. If any known or potential safety risk is associated with the samples, provide relevant Risk Assessment & MSDS in advance of the analysis-taking place.
6. A safety check is carried out by the CREST RPS or a trained member of staff on a monthly basis to ensure that the XRF is kept in good working order.
7. Report any malfunctions of the instrument immediately to the CREST RPS and the RPO (City Campus)/DRPO(City Campus). Remove the battery immediately and place the unit back into the safe. Record in the relevant logbook.
8. The Risk Assessment for the XRF is available at I:\Quality\Controlled Records\Equipment\183-XRF. The Bruker XRF produces ionising radiation using high voltage sources. Care must be taken to ensure the safety both of the operator of the diffractometer and nearby researchers.

2.8.5 Materials/Equipment

1. XRF: stored in the Radiation Protection Safe in the Consultancy Laboratory of CREST.
2. Dedicated Consultancy Instrumentation Laptop.

2.8.6 Procedure

The XRF user manuals are located on the dedicated laptop and at I:\Quality\Controlled Records\Equipment\183-XRF, they are used in conjunction with this procedure.

NOTE 1: The following describes each component of the XRF:

Armed indicator: Indicates that the instrument is ready to take a measurement.
Auxiliary trigger: Allows dual hand operation as required in certain countries.
Battery: Provides power to the instrument.
Battery door lock: Keeps the battery secure.
Collimator hatch: Accesses the collimator/filter assembly.
Examination window: Source location of X-rays.
Ports Provide connections for USB, remote, USB flash drive, and power.
Power switch: Powers the instrument on and off.
Proximity sensor: Prevents the instrument from activating without a sample in place.
Touch screen: Controls the instrument through a pressure sensitive user interface.
Trigger: Initiates a measurement.
X-ray warning light: Warns when X-ray is activated.

NOTE 2: The Power Sources:

The analyser is supplied with two Lithium ion (Li-ion) batteries and a battery charger with a cord. To install the battery into the TRACER5i XRF, slide in the battery and close the door until the locking clip clicks. Note that the battery can be inserted completely in only one configuration. To remove the battery, press the battery door button, open the door and pull out the battery.

Figure 1. Insertion of battery in TRACER 5i XRF.

NOTE 3: To charge the battery:

To prolong the battery life, ensure that the ambient temperature during charging is between +5 °C and +45 °C (40 °F to 115 °F). Plug the power adapter into the back of the charger. Plug the power cord into the power adapter. Plug the power cord into a wall outlet. Insert the battery into the charger with the Bruker name on the left side. During charging, the green light blinks. A solid green light indicates the battery is fully charged. The

duration the charge lasts, depending how the instrument is used, can vary from about four to eight hours.

NOTE 4: Filter:

The TRACER 5i has interchangeable features including filters. The filter is inserted into the filter holder, which is attached to the collimator with a screw. **Filter types:** The filter allows to focus on key elemental ranges to identify elements at detection limits. The instrument comes with different filter options and filter holders marked in different colours to indicate the filter type.

NOTE 5: The collimator:

The collimator determines the size of the spot on the sample to be tested. For most applications, 8mm is best. The 3mm collimator reduces the focal point size and hence the analysed area. For safety reasons, a collimator must be installed at all times. If a collimator is installed then the size is displayed in the status bar and recorded in the data file. If it is not installed the instrument is prevented from entering the armed state and will not produce X-rays.

General Use:

1 Proposed use must be scheduled, through the RPS, using the weekly equipment schedule and may only be carried out by approved users. The key to the safe is stored in the CREST Office.

2 Affix the “Radiation in Use” sign to the Consultancy Lab door prior to use**.**

3 Remove the XRF from the Radiation Protection safe. All accessories are located in the black case on top of the safe.

4 Check that the proline window is intact, if not replace as per manual.

5 Insert a fully charged battery or connect the AC adapter included. Press the power switch.

6 A radiation warning will display, pull the trigger.

Figure 2: Radiation warning

7 Wait for the Logon Screen to appear. Tap the Logon button and log on as User (12345) or in supervisor mode.

8 Set up as shown in Figure 3 using the Test stand and connect to the laptop using the USB cable supplied. This allows for remote control use of the XRF. Ensure that the Laptop is >1m from the unit and the steel window is facing away from user or any other personnel. Press the red button on stand for removal. <u>NB: The user must be logged on before attaching the XRF to the Laptop.</u>

XRF orientation **Release button** **XRF connected to Laptop** **XRF > 1m from laptop**

Figure 3: XRF set up for use

9 Reference Bruker Toolbox Manual for instruction on remote control use of the XRF.

10 Press Bruker RemoteCtrl on the desktop, press file, click on device shown, 900G7841-this will connect the laptop to the XRF. The unit display is shown on screen.

11 Select the application matching your sample from the “Application Menu”

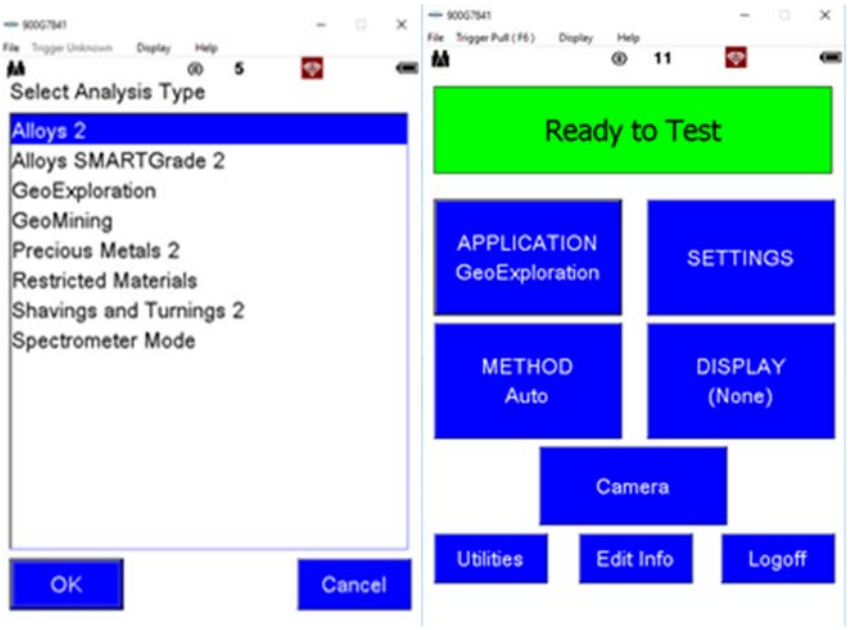


Figure 4 Screen Display

11. The Ready to Test screen includes various touch buttons:

BUTTON	PURPOSE
APPLICATION	Specifies the purpose for which the instrument is used.
METHOD	Specifies a calibration application to the selected application.
SETTINGS	Specifies trigger behavior and measurement duration
DISPLAY	Specifies how measurement results are displayed
Camera	If a camera is installed, accesses camera features.
Utilities	Accesses options to display results and back up data.
Edit Info	Allows measurement data to be named and described.
Logoff	Logs off the current user and displays the login screen.

2.8.7. The **APPLICATION button** accesses application options. The intended use of the instrument determines which option to select. Possible options which are available applications based on the purchased configuration can include:

Standard alloys, GeoExploration, GeoMining, Precious metals, Restricted materials and other applications.

For each application, settings can be defined, which include: Method, Display options, Phase durations (measurement times), Manual or automatic trigger.

Whenever the application is changed, settings are changed to those defined for that application.

2.8.8 The SETTINGS Button:

The options in **SETTINGS** define trigger behaviour and multiple measurement times, or phases. The selected application determines available phases. For example, Alloys has two phases and Geo Exploration can have three phases.
This will be covered in more detail in section 2.8.20.6, the quality control (QC) check section.

2.8.8.1 Spectrometer Mode:

If Spectrometer Mode was selected under APPLICATION, then under SETTINGS one of the following screens is displayed, depending on instrument type.

To select a standard spectrometer setting:

1. From the Ready to Test screen with application Spectrometer Mode selected, tap SETTINGS. The Spectrometer Settings screen is displayed.
2. To select a defined setting, tap the down pointing triangle below Reset. A dropdown list is displayed.
3. Tap a selection. The setting name is displayed in the field and the kV and µA fields reflect appropriate settings.
4. Tap the down pointing triangle, scroll down and tap a filter name. The filter name is displayed.
5. Define System Settings as necessary.
6. Tap OK. Settings are saved and the Ready to Test screen is displayed.
7. Default settings determine the length of the measurement. If Use Default Settings is checked, phase options are not displayed. If Use Default Settings is unchecked then phase options are displayed.

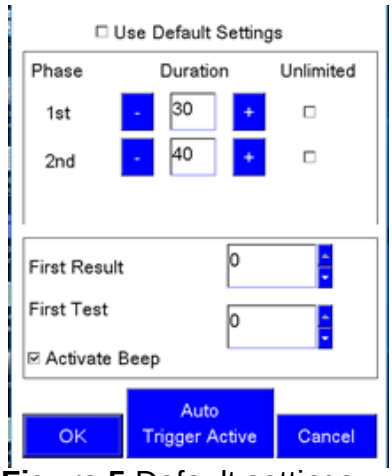


Figure 5 Default settings.

2.8.9 METHOD Button:

The instrument analyses a sample using a specifically selected calibration, or method. The selection can be automatic or user-specified. The selected application determines available options in METHOD.

Figure 6 Automatic calibration selection

To select a method **other than Automatic Calibration Selection**:

1. From the Ready to Test screen, tap METHOD. The Select Method screen is displayed.
2. Ensure that Automatic Calibration Selection box is not checked. If it is checked, tap it. The box is empty.
3. Tap a method name. The method name is highlighted.
4. Tap OK. The Ready to Test screen is displayed with the name of the selected method on the METHOD button.

2.8.9.1. Phase Description:

1st phase: A quick, high level assay used to refine settings for the subsequent phase.

2nd phase: A more specific and accurate assay based on first phase information.

3rd phase: An additional assay available for some applications.

Accuracy: The longer the measurement, the more accurate the results. Every second to several seconds of a measurement, depending on the application, displayed results are updated.

2.8.9.2. Phase length:

To manually set the length of each phase:

1. From the Ready to Test screen, tap SETTINGS. The SETTINGS screen is displayed.

2. Ensure that Use Default Settings box is not checked. If it checked, tap it. Phase options are displayed.

3. Ensure the box below Unlimited is unchecked. The box is empty and fields previously greyed out are available.

4 Set each phase duration in seconds by tapping either the minus sign (-) or the plus sign (+) to decrease or increase, respectively, the measurement duration. The field reflects the number change.

OR

Tap the field. A numeric keyboard is displayed.

5. On the keyboard, tap a number and OK. The keyboard is removed and the field reflects the number change.

6. For subsequent phases, repeat steps 3-5. To disable subsequent phases, set duration to 0.

7. Tap OK. The Settings are saved and the Ready to Test screen is displayed.

One phase: If a method does not use multiple phases, only one phase is displayed.

Unlimited: Unlimited indicates the measurement continues while the trigger is pressed and ends when the trigger is released. It is not a timed measurement but is limited to 300 seconds.

If Unlimited is checked for a phase, the instrument will NOT use that phase or additional phases.

First result: The interval in seconds between the start of an assay and when the First Result displays can be set manually. This assures that results from shorter, less accurate test times are not displayed.

First test: The time can be set manually before the First Test displays and records. Longer test times are more accurate. First Test settings must always be as long as, or longer, than First Result times.

Results of the first test are compared to the Grade Library and, if a match is found, the grade ID is displayed.

Activate beep: This checkbox determines if an audible alarm sounds when a grade match is found.

2.8.9.3 Trigger options:

These include either manual or auto:

13.3.1. Manual Trigger Active – The instrument operates while the trigger is pressed or until safety criteria are exceeded.

13.3.2. Auto Trigger Active – The measurement begins when the trigger is pressed and released. Analysis time is controlled by defined phase durations. The measurement can be stopped at any time by pressing and releasing the trigger again.

2.8.10 DISPLAY Button:

How measurement results are displayed is determined by options selected under the DISPLAY button.

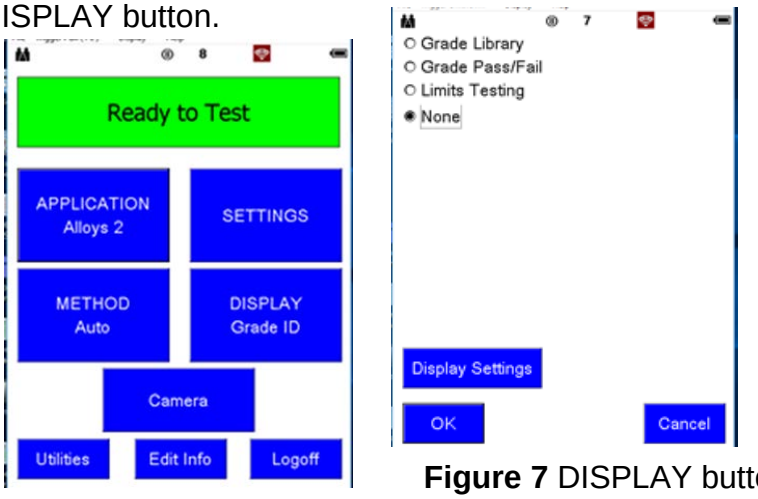


Figure 7 DISPLAY button.

Limits Testing: Limits Testing displays measurement results against minimum and maximum values.

None: Selecting None provides a sample analysis without a comparison to a grade library.

The Results screen displays the following information:
Index number / Date and time of the assay / Assay duration in seconds / Detected elements / Element percentages or PPM and their statistical +/- error range. (The longer the measurement, the smaller the +/- error range.)

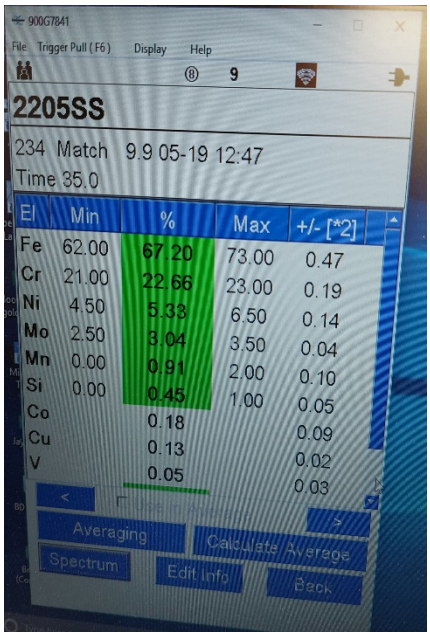


Figure 8 Elemental percentages.

2.8.10.1. Display Settings:

How measurement results are displayed is specified on the Display Settings screen.

1. Display Units: Measurement results can be displayed in PPM (Parts per million) or % (Percent).
2. Display Size: The font size on the Results screen.
3. Sort By: Results are sorted by element atomic number (El No) or alphabetically by element name (El Name).
4. Enable LOD Display: Results include analysed elements with an assay less than the limits of detection (LOD). The LOD is defined as n*STD, where n is a number from 1 – 5 and STD is standard deviation.
5. Number of Decimals: The number of digits displayed to the right of the decimal point of a percent value.
6. STD Display Limit: The number of standard deviations on the Results screen. The error displayed with an assay is n*STD. If the assay is less than n*STD and Enable LOD Display is checked, the assay is displayed as <LOD.

2.8.10.2. Element Display Order

Element order can be customised, rather than sorting by element atomic number or alphabetically by element name. To customise the element order on the Results screen **one element at a time**:
1. Under DISPLAY and then Display Settings, tap Element Display Order. The Element Sort Page is displayed.

2. Under the Element List, tap the name of the first element to be displayed in a result list. The selected element name is highlighted.
3. Tap the right pointing arrow. The selected element name is moved to the Sort Order list.
4. Populate the Sort Order list with element names in the desired order by repeating steps 2 and 3. The Sort Order list is populated with element names in the order names are moved over.
5. To move an element name back to the Element List on the left, tap the name under Sort Order and then the left pointing arrow. The selected element name is moved back to the Element List.
6. To save the modified sort order, tap OK. When assays are taken, results are listed in this order.

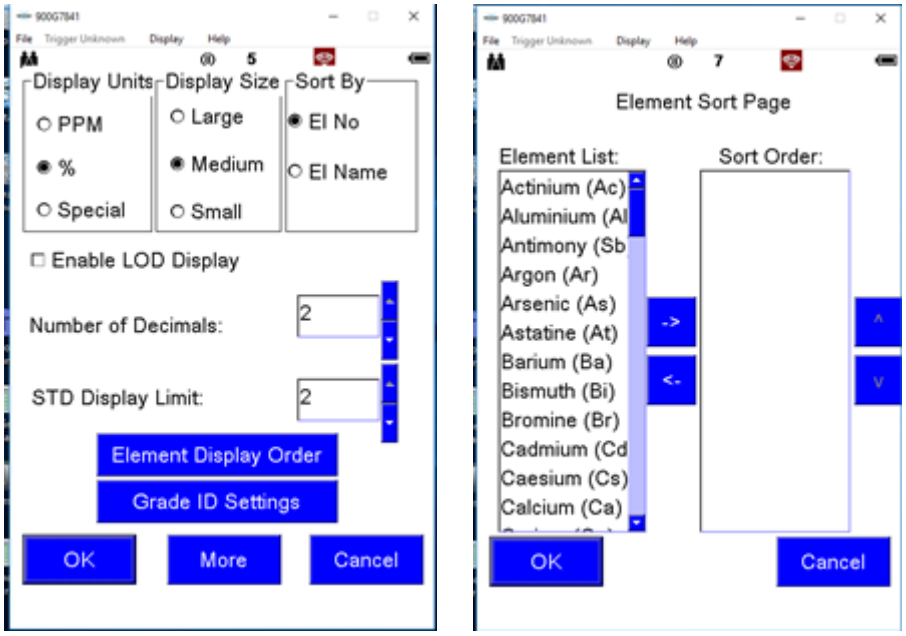


Figure 9 Elemental display order

2.8.10.3. Sorting multiple at a time:

To customize the element order on the Results screen multiple elements at a time:
1. Under DISPLAY and then Display Settings, tap Element Display Order. The Element Sort Page is displayed.

2. Under the Element List, tap multiple element names to be displayed in a result list. Selected element names are highlighted.

3. Tap the right pointing arrow. The selected element names are moved to the Sort Order list in alphabetical order.

4. To change the order of elements in the Sort Order column, tap an element name. The element name is highlighted.

5. To move the element name up or down in the list, tap the up pointing or down pointing cursor. The selected element name moves up or down accordingly.

6. To save the modified sort order, tap OK. When assays are taken, results are listed in this order.

2.8.11 Utilities Button:

The Utilities button accesses options to:

Display Results of measurements.

Back up Data by copying or moving, with the option to delete.

Allow Remote Control of the instrument.

Figure 10: Sample ID

1. Before a measurement is taken, an assay can be named and described using **the Edit info button**. This information is saved to the Results.csv file and the <index>-<Application>.pdz (e.g., 234-Alloys.pdz) spectrum file.

2. Sample ID: Whatever is entered in the first field under Value is what is displayed in the Sample ID field in Results (and the Name field in Report Generator in Bruker Instrument Tools). If Operator is the first value, then the second value is used for Sample ID.

3. File List: More than one source file may be available with different or additional Field Names. To access additional source files, tap the downward pointing arrow to the right of the File List field. A dropdown list is displayed. Tap a selection.

4. Averaging: Values from selected measurements can be averaged. Assays can be selected individually or by default. Only assays taken with the same method can be averaged.

5. Average results are: Calculated for elements and +/- values. If an element is missing from one of the averaged results, the value is 0. For example, results of three assays are averaged. Al is detected at 60%, 60%, and 0%. The average is 40%. Analysed for Grade Matching and Pass/Fail. Saved in the results list and in Results.csv.

6. Enable averaging: When Enable Averaging is checked for an assay, averaging is available to all stored in the Results.csv file. The Use in Average and Calculate Average options are displayed on the Results screen.

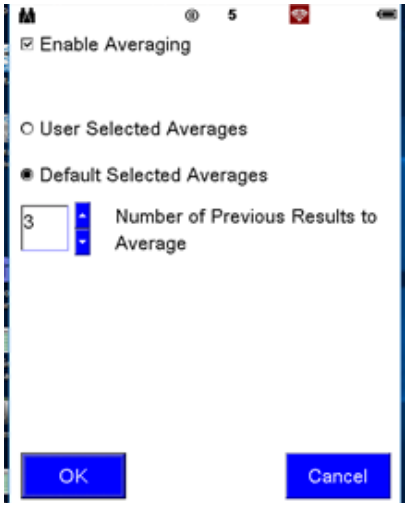


Figure 11 Enabling average.

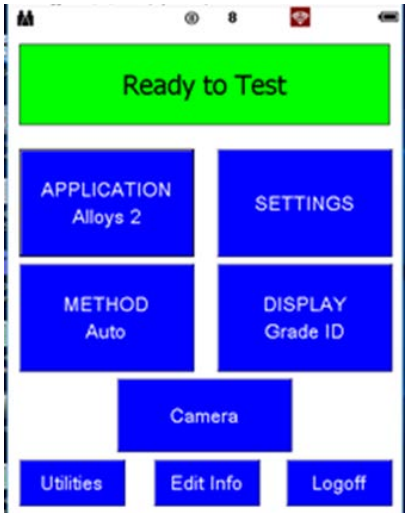


Figure 12 To label analysis.

2.8.12. To label subsequent analysis:

1. From the Ready to Test screen, tap the **Edit Info button**. The Sample ID Fields screen is displayed.
2. Double tap a field under Value.* A keyboard is displayed.
3. Enter appropriate information. The field reflects the change.
4. Tap OK. The keyboard is removed and information is saved in the field.
5. Repeat steps 2 – 4 as necessary.
6. To save changes to the Sample ID Fields screen, tap OK.
7. The Ready to Test screen is displayed and subsequent assays are labelled accordingly until these settings are changed.

8 If the List checkbox, available in Supervisor Mode, is checked for the applicable Field Name, when a field under Value is tapped once, a dropdown list is displayed, rather than a keyboard. Select from the list or <Add New>, as described below.

9. Adding values with <Add New>:

Note that once a value is added, it cannot be removed from the list.

2.8.13. To add values:

1. To add values to a **dropdown list in the List**, checkbox available in Supervisor Mode is checked for the applicable Field Name:
2. From the Sample ID Fields screen, tap a Value field. A dropdown list with <Add New> is displayed.
3. Tap <Add New>. The keyboard is displayed.
4. Enter a value and tap OK. The new value is displayed in the Value field.
5. Tap OK. The change is saved and the Ready to Test screen is displayed.

2.8.14. Preparation of a liquid sample:

Figure 13 Preparation of a liquid sample**.**

1. The XRF sample cup (double open ended with caps) is set up as follows:
Tear a small amount of the Prolene thin film, place the hollow plastic open ended container on it in such a manner that the plastic ring encloses the prolene when it is placed on top of it and pushed down so that it forms a seal. Invert this set up and add the liquid sample to this.
2. Place the sample over the window of the unit, making sure that the proximity switch is covered. Place the lead cover, supplied, on top of the sample to ensure that the x-rays produced are contained.

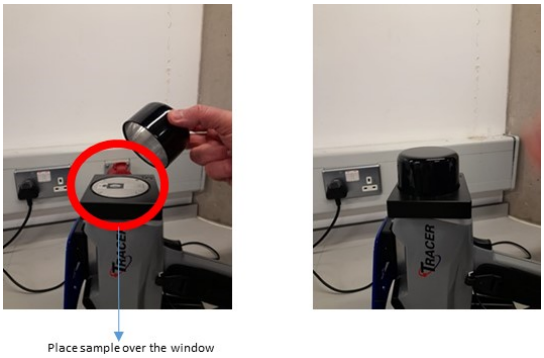


Figure 14: Orientation of the sample holder

3. The armed LED, at the side of the XRF, will light yellow to show that the IR proximity switch is covered (required for X-Rays to be generated).

4.Press the Trigger Pull button on the Display screen to begin analysis; **X-Rays are generated during this time. The lights on the side of the XRF will flash Red.**

5. In cases where the sample is too small to cover the proximity switch contact a supervisor/RPS in order to get the proximity switch disabled for the duration of the testing. This must be re-enabled straight after use.

6. If preferred, place a small amount of aluminium foil to cover the proximity sensor and perform the analysis.

7. In cases where the sample is too big/bulky for use in the test stand, the XRF may be used without the stand this is not the recommended use.

8. The wrist strap must always be used when carrying/holding the XRF.

9. If the XRF is damaged in any way, remove the battery and contact the RPS immediately. (Bruker +1(509) 783-9850 or support@bruker.com)

10. Remove all data from the unit once completed.

2.8.15 Results:

Results of a measurement are displayed two ways, during and immediately after a scan; **it is recommended that results after a scan is used.**
To review the results of a past analysis:

1. From the Ready to Test screen, tap the Utilities button. The Utilities screen is displayed.

2. Tap Results. A table showing every assay stored in memory, in reverse order of Index number (most recent measurement at the top), is displayed.

3. Touch scroll up and down, left and right, to see all assay names. Tap a measurement to review. The sample is highlighted.

4. At the bottom of the screen, tap the sample's index number. Results of the sample's assay are displayed.

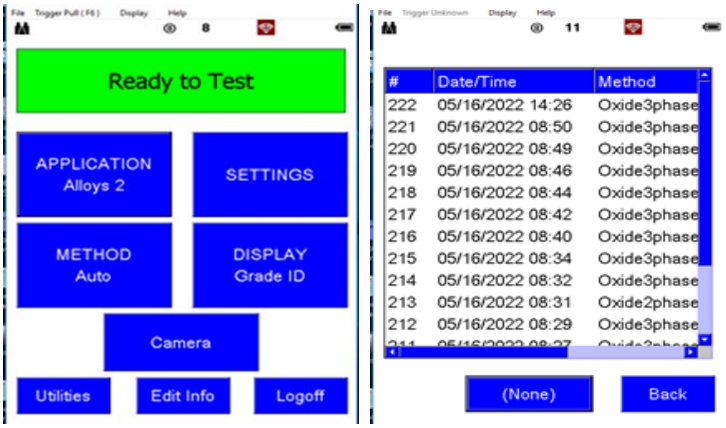


Figure 15(a) How to locate results from analysis

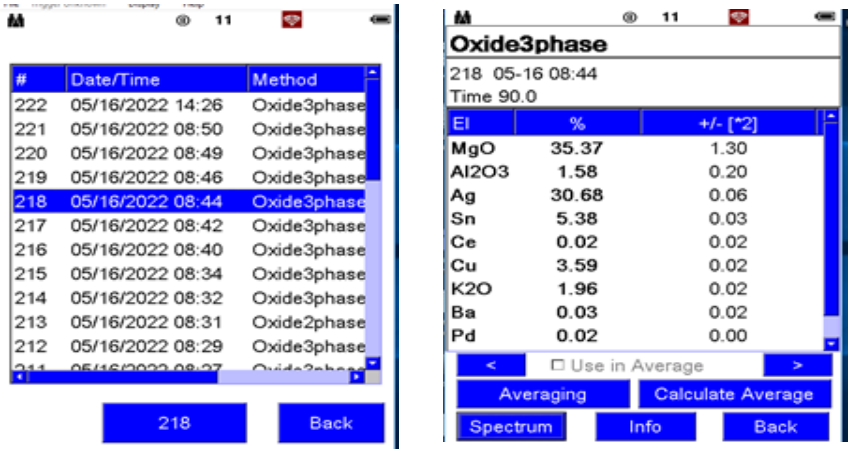


Figure 15(b). How to locate results from analysis

2.8.15.1. ID match:

If the sample matches grade IDs in the library, up to three matching IDs are displayed. If not, the application name is displayed.
1. Assay information: The following information is provided for quick reference: Index number of the sample / The date and time the assay was measured / Length of the measurement in seconds / If averaging, the index numbers of the selected assays.
2. Columns: Column Heading Description
El: Element symbol.

3. Min and Max: Minimum and maximum percent allowed according to the grade library. Note that some applications do not use a grade library and Min and Max are not displayed.
% or PPM of the element in either percent, parts per million.
+/- [*n]: Standard deviation.
To sort data in a column in descending or ascending order – tap a column heading.
4. < and > To view different assays ordered by index number – use the back and forward options, < and >.
5. Info To display the assay's name, ID, and other information, if applicable – tap Info. This information cannot be edited.

2.8.16. Spectrum:

Elemental spectrum:
To view the spectrum and specific elements for the selected assay:

1. From the Results screen of a specified assay, tap Spectrum. The Spectrum screen is displayed.

2. Tap El. A list of element symbols is displayed.

3. Scroll down to see all elements. Tap one. The element is highlighted.

4. Tap OK. The spectrum is displayed with one or more red vertical bars identifying peaks for the selected element. El is now replaced with the symbol of the selected element.

5. To identify a spectrum peak, tap it. One or more red vertical bars is displayed and the element symbol is displayed on the El button.

6. The x-axis of the spectrum indicates the ionisation energy (keV) and the y-axis the Intensity (counts per second (CPS). The higher the counts of a particular element, the higher will be its presence at that point or area of interest.

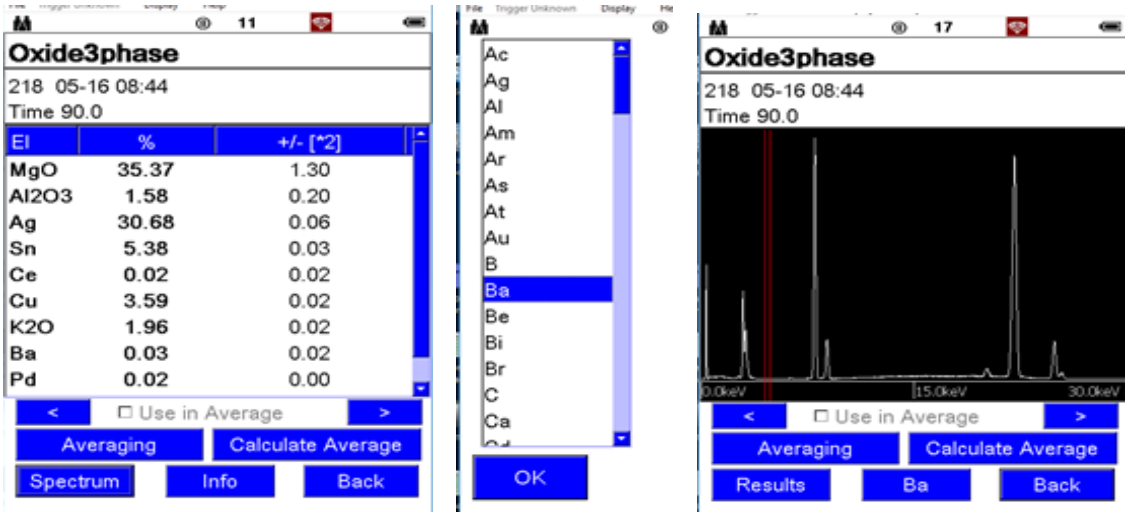


Figure 16: How to identify spectrum peaks

2.8.17. Axis toolbar:

The axis toolbar manipulates the spectrum display to better view details. To display it, tap the screen and hold.

1. X+ Stretches the x-axis (keV) scale to zoom in on the spectrum. To view the entire spectrum, tap and drag horizontally.
2. X- Compresses the x-axis (keV) scale to zoom out from the spectrum.
3. X0 Re-centres and returns the spectrum to the original x-axis scale.
4. Cent. Re-centres the spectrum on both the x- and y-axes.
5. Y+ Stretches the y-axis (count rate) scale.
6. Y- Compresses the y-axis (count rate) scale.
7. Y0 Returns the spectrum to the original scale along the y-axis.
8. Def. Restores the spectrum to its default setting; the spectrum is re-cantered and the original scale along both axes is restored.

2.8.19. Back up/saving data:

1. This option under **Utilities** provides the ability to:

Copy – copies data to an external location, leaving data in the instrument memory. Move – copies data to an external location and deletes data stored in the instrument. Delete – removes data from the instrument memory without copying.

2. Copy/move: To copy or move data from the instrument to an external location.
3. Place a USB stick into the USB port in the XRF Tracer 5i. Tap the Utilities button and Backup Data. The Backup Data screen is displayed.
4. Tap on option to Copy or Move.
5. If moving, check the Reset Assay file name counter box, if desired. The box is checked.
6 Tap the Data File Source Location drop down arrow to view possible source files and select one.
7. Tap the Data File Destination Location drop down arrow to view possible destinations and select
8. Tap Execute. After files are copied in this case, the Utilities screen is displayed.
9. Delete: To delete all assays from the selected Data File Source Location on the instrument, tap Delete and Execute. The measurements are deleted and the Utilities screen is displayed.

Figure 17: How to save data/results

2.8.20. Monthly Safety Check:

The following safety check is carried out by the RPS/Trained user on a monthly basis and recorded in the XRF Safety Check Log Book/scanned barcode.

1. **Sample Window**: Check that the Proline Window is intact.
2. **Radiation Warning Note:** Turn on the XRF and logon to supervisor mode, check that the Radiation warning appears and warning lights come on.
3. **Radiation Warning Light:** Set up for sample as in 2.8.6. Place a sample over the window as shown in Fig 3 and press Trigger pull. The red lights must come on when the sample is running.
4. **Proximity Sensor Check:** Place the sample in such a way that the proximity switch is not covered. The sample run should stop. If this does not occur check under Utilities>System Setup>Safety>Proximity Sensor, that the proximity sensor is enabled.
5. **Backscatter Check:** Detach the XRF from the laptop and remove from the stand. Pull trigger, the error message “Count Rate” should appear and measurement stop.

6. **Quality Control (QC) Check:** This should be performed once a month. This test verifies assays measured and recorded on the instrument are accurate and should be performed once a month, preferably when the monthly safety check is performed.

To verify that the XRF is calibrated correctly, 5 quality control checks are performed with different materials. These materials are stored in a green case inside the black case:

- Silver round precious metals check
- SAC 305 Solder check
- CSM2 GeoExploration check
- Duplex 2205 check
- EC681M plastic check

QC Check	Application	Method	Settings	
Silver round check	Precious Metals 2	PrecMetals	15 seconds	
SAC 305 Solder check	Restricted materials	Automatic Calibration	Phase 1: 30seconds	Phase 2: 30seconds
CSM2 check	GeoExploration	Oxide 3 Phase	3 Phases: Each 20 seconds	
Duplex 2205 check	Alloys 2	Automatic Calibration	Phase 1: 5 seconds	
EC681M Plastic check	Restricted materials	Automatic Calibration	Phase 1: 30seconds	Phase 2: 30seconds

Table 1 Experimental conditions for each quality control check.

For the Silver round quality control check, set up the following:

6.1. Set APPLICATION to Precious Metals 2, set Method to PrecMetals and settings to 15 seconds.

6.2**.** From the Ready to Test screen, measure (pull trigger) for the supplied material sample 10 times.

6.3. Average the 10 assays.

6.4. Compare the average measured value for each element against the Acceptance Limit maximum and minimum on the Check Sample Report supplied with your instrument.

6.5**.** If all averaged measurements fall within MAX and MIN limits, continue to use the

Instrument – see table no.2 for limits.

If averages fall outside MAX and MIN limits, with respect to standard deviation, check the following:

- Measurement times
- Sample surface
- Instrument window

Repeat the above steps 6.1 to 6.5, changing APPLICATION, method and settings to whatever is required for the quality control check of the remaining material.

6.6**.** Contact Bruker if checks 2.8.20.2, 2.8.20.3, 2.8.20.5 and 2.8.20.6 fail and remove the XRF from use.

	LIMITS	**Cu**	**Ag**					
SILVER ROUND	Min	6.841	92.815					
	Max	7.185	93.159	**Pb**	**Sn**			
SAC 305	Min	4383	34000	742	952000			
	Max	5338	37000	872	955000			
		Cu	**K_2O**	**Pb**	**Mn**	**Fe**	**Al_2O_3**	**Ca**
CSM2	Min	0.0157	4.31	0.074	0.085	1.49	9.08	0.55
	Max	0.0263	4.76	0.0932	0.125	1.72	11.99	0.64
		Cu	**Cr**	**Si**	**Mn**	**Fe**	**Ni**	**Mo**
DUPLEX 2205	Min	0.064	22.444	0.292	0.517	66.146	4.971	2.969
	Max	0.206	23.12	0.552	1.138	67.866	5.708	3.153
		Cl	**Cr**	**As**	**Br**	**Cd**	**Hg**	**Pb**
EC681M	Min	268	0	0	1415	83	0	0
	Max	398	110	83	1545	213	71	109

Table 2 The minimum and maximum acceptance limits for each material.

File #	DateTime	Al_2O_3	Al_2O_3 Err	K_2O	K_2O Err	Ca	Ca Err	Mn	Mn Err	Fe	Fe Err	Cu	Cu Err	Pb	Pb Err
421	06/08/2022 12:57	11.0476	0.3674	4.5527	0.0367	0.6025	0.0131	0.0996	0.0054	1.5936	0.0152	0.0216	0.0013	0.084	0.0029
422	06/08/2022 12:59	11.0158	0.3667	4.5455	0.0367	0.6083	0.0131	0.1031	0.0055	1.5682	0.0151	0.0217	0.0013	0.0826	0.0029
423	06/08/2022 13:00	10.8211	0.3656	4.5189	0.0366	0.6106	0.0132	0.1028	0.0055	1.5833	0.0152	0.0201	0.0013	0.0858	0.0029
424	06/08/2022 13:02	11.3055	0.3706	4.5653	0.0368	0.6089	0.0131	0.1046	0.0055	1.5958	0.0152	0.0217	0.0013	0.0848	0.0029
425	06/08/2022 13:03	11.0017	0.3665	4.5733	0.0368	0.5997	0.0131	0.1052	0.0055	1.5716	0.0151	0.0207	0.0013	0.0826	0.0028
426	06/08/2022 13:04	11.108	0.3678	4.5694	0.0368	0.6289	0.0133	0.0999	0.0054	1.5856	0.0152	0.0213	0.0013	0.0828	0.0028
427	06/08/2022 13:06	11.0508	0.3674	4.5732	0.0369	0.6048	0.0131	0.0993	0.0054	1.5848	0.0152	0.0199	0.0013	0.0831	0.0028
428	06/08/2022 13:07	11.173	0.3698	4.5591	0.0368	0.6077	0.0131	0.1051	0.0055	1.5897	0.0152	0.0216	0.0013	0.0853	0.0029
429	06/08/2022 13:08	11.2625	0.3689	4.5839	0.0369	0.6157	0.0132	0.1006	0.0054	1.5852	0.0152	0.0223	0.0013	0.0834	0.0028
430	06/08/2022 13:09	11.0244	0.3666	4.558	0.0368	0.613	0.0132	0.1054	0.0055	1.5893	0.0152	0.0198	0.0013	0.0856	0.0029
	Average	11.081		4.5599		0.6100		0.1026		1.5847		0.0211		0.084	
	Minimum Acceptance Limit	9.08		4.31		0.55		0.085		1.49		0.0157		0.074	
	Miaximum Acceptance Limit	11.99		4.76		0.64		0.125		1.72		0.0263		0.0932	

Table 3 shows a worked example for the QC check using CSM2 soil material – the average of all the elements are within specifications

APPENDICES

Appendix (i) *Questionnaire for SOP (11-183).*

Circulate electronically to all CREST staff on the training list. All completed training questionnaires are saved in the SOP Training Folder of the relevant SOP on the I:\Quality\Controlled Documents\SOP\Current SOP\SOP XX-XXX\SOP XXX-XXX Training.

Questionnaire for SOP 11-183

Q1. What are the safety requirements for use of the XRF?
Q2. Who can use the XRF? What training must be completed prior to use?
Q3. Where are the instruction manuals located?
Q4. What is the minimum distance from the XRF to the laptop during use?
Q5. When do the lights on the side of the XRF flash red?
Q6. What do you do if the unit is damaged during use?
Q7. What are the main areas covered during the monthly safety check?

The trainee and trainer hereby confirm that the trainee:

- *has read and understood this SOP; and*
- *agrees to carry out related actions according to the instructions in this SOP.*

	NAME, TITLE (PRINT CLEARLY)	**SIGNATURE**	**DATE**
TRAINEE:			
REVIEWED BY (TRAINER):			

2.9 Standard Operating Procedures for Use of Uranyl Acetate for Transmission Electron Microscopy

2.9.1 Safety information

Uranyl acetate is a water-soluble uranium compound and is used as a stain in electron microscopy.

Uranyl acetate principally contains the isotope 238U of uranium. The specific activity of 238U 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. 238U is an alpha emitter and there are also beta and gamma emitting decay products.

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

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 a relatively high risk arising from internal exposure following inhalation or ingestion. It is therefore essential to adopt appropriate precautions when handling unsealed uranium salts to minimise this risk:

- Reduce the amount being handled as much as possible
- Contain the unsealed sources to prevent contamination
- Maintain a high level of cleanliness

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 10g, respiratory protection is not necessary. Avoid contamination of bench surfaces by using spill trays (metal or plastic) with disposable coverings such as benchcote and clean the surface after use.

Radiation levels are monitored in the area to confirm compliance

2.9.2 Storage

Any stock solution or powder must be labelled with the radioactive warning sign and stored in a locked cupboard. When storing in a wooden cupboard, spill trays (metal or plastic) must be used to prevent wood contamination, which is very difficult to remove. Lead shielding is not necessary as the radiation is easily contained by the storage cupboard or cabinet. 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.
A designated forceps to be used for staining should also be stored together with the uranyl acetate powder in the locked cupboard.

Stained grids should also be stored in the locked cupboard.

2.9.3 Record keeping

The batch number of the uranyl acetate powder will be recorded in a laboratory notebook. Each time the 3% uranyl acetate solution is made up, the amount of uranyl acetate taken from this batch will be recorded, e.g. 1.5 grams. The batch number will also be used to label all solutions made from this batch of powder. The laboratory notebook will be updated each time the solution is used, and the amount disposed will be recorded. The results of any monitoring of work areas / personnel after each use will also be recorded.

2.9.4 Disposal of waste

The liquid waste generated by the staining procedure will be disposed of according to the EPA Guidance Note on the Disposal of Prepared Uranium/Thorium Compounds (May 2010).
The liquid waste (approx. 1-5 ml 3% uranyl acetate solution in approx. 20-100 ml distilled water) will be flushed down a designated drain/access point, which is directly connected to the foul sewer system. Approximately 10 times the volume of water will also be flushed down the drain/access point to achieve further dilution. The drain/access point will then be washed with dilute acetic acid solution (5% acetic acid) to ensure that no residue of the compound is adsorbed on its surface.
Solid contaminated waste e.g. filter papers, tissues, benchcote, parafilm, staining petri dish, pipette and gloves, will be disposed of in a designated and dated waste bag and stored. The bag will be monitored prior to disposal to ensure that it is at background level before disposal.

2.9.5 Methods

2.9.5.1 Preparation of 3% Saturated Uranyl Acetate Staining Solution

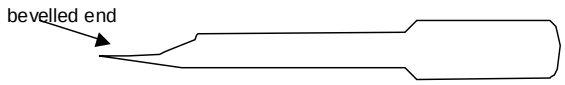
Materials:

Uranyl acetate powder, 50 ml capacity glass bottle with lid, plastic transfer pipette, razor blade/scalpel, balance, graduated cylinder with 50 ml of distilled water, sonicator, parafilm, benchcote, labelled plastic waste bag.

Personal protective equipment - lab coat, safety goggles, double gloves (must satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it), face mask (must be approved to government standards such as CEN (EU) or NIOSH (US))

Procedure:

1. One day in advance, inform all RESC laboratory members by email that access to the lab will be restricted during the time you are making up the uranyl acetate solution
2. On the day, place a warning sign on the RESC laboratory doors before commencing work
3. With razor blade/scalpel, cut tip off plastic transfer pipette at an angle to form into a spatula as shown in diagram:



4. Place a fresh sheet of benchcote in the fume hood
5. Place uranyl acetate powder, plastic transfer pipette spatula, balance, glass bottle with lid, graduated cylinder with 50 ml distilled water, sonicator, parafilm and labelled plastic waste bag in the fume hood.
6. Place tissue paper and the bottle onto the balance to tare.
7. Use the plastic pipette spatula to carefully weigh out 1.5 grams of uranyl acetate powder into the bottle.
8. Discard the pipette into designated plastic waste bag.
9. Remove bottle from balance, pour 50 mL of water into bottle and place lid on.
10. Wipe any spillage of powder with a moistened tissue. Discard this tissue and the tissue from the balance into designated plastic waste bag.
11. Place bottle of uranyl acetate solution (with lid on) in sonicator, also in fume hood, and sonicate up to one hour.
12. When sonication is complete, wrap aluminum foil around the bottle to protect from light and wrap parafilm around the lid of the bottle. Label bottle with date, contents, hazard warnings as per uranyl acetate container and your name. Store 3% uranyl acetate solution in the designated locked cupboard.
13. Dispose of any contaminated tissue, face mask, outer gloves and benchcote into plastic waste bag

14. Before returning the balance to the lab bench, clean with moistened tissue and monitor for any contamination.
15. Monitor the fume hood for any radioactive contamination
16. Wash hands and monitor for any radioactive contamination
17. Record, with the date and your name, details of batch number of the uranyl acetate powder, the amount of uranyl acetate taken from this batch, e.g. 1.5 grams, any solid waste (tissues, gloves, face mask, benchcote, plastic ware) disposed of and the results of any monitoring of work areas / personnel after making up the solution.

2.9.5.2 Staining Grids for Transmission Electron Microscopy using uranyl acetate

Materials:

3% uranyl acetate staining solution, plastic transfer pipette, petri dish with top lid covered in aluminum foil and one piece of parafilm to fit inside petri dish, second petri dish, distilled water in a wash bottle, fine forceps, timer, filter paper, bench coat, labelled plastic waste bag and labelled waste container.

Personal protective equipment - lab coat, safety goggles, double gloves (must satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it), face mask (must be approved to government standards such as CEN (EU) or NIOSH (US))

Procedure:

1. One day in advance, inform all RESC laboratory members by email that access to the lab will be restricted during the time you are using the uranyl acetate solution
2. On the day, place a warning sign on the RESC laboratory doors before commencing work
3. Working in the fume hood, place all materials required onto a fresh sheet of benchcote
4. Pipette one drop of uranyl acetate staining solution from the top surface of the solution i.e. do not pipette too deeply from the solution, for each grid to be stained onto the parafilm in the petri dish
5. Float the inverted grid (sample facing down) on the drop of stain for 5-10 minutes
6. Place the foil covered lid onto the petri dish
7. Carefully remove the grid and rinse using the wash bottle so the water flows down the forceps onto the grid for approx 30 seconds into the waste container
8. Blot the grid onto filter paper and wick out the water from between the tines of the forceps using filter paper
9. Place the grid onto clean filter paper in a labelled petri dish and allow to dry for at least 20 minutes before viewing in electron microscope

10. Wrap clean parafilm around the lid of the uranyl acetate bottle and return to the locked cupboard.
11. Place all filter papers, tissues, benchcote, parafilm, staining petri dish, pipette and outer gloves into labelled plastic waste bag
12. Before returning the forceps to the locked cupboard, wipe with moistened tissue and monitor for any contamination. Similarly monitor the stained grids and place in the locked cupboard until needed.
13. Monitor the fume hood for any radioactive contamination
14. Wash hands and monitor for any radioactive contamination

Record, with the date and your name, details of the volume of 3% uranyl acetate used and disposed of or stored, any solid waste (tissues, gloves, face mask, benchcote, plasticware) disposed of, and the results of any monitoring of work areas / personnel after making up the solution.

2.9.5.3 Spill procedure

If spillage of the uranyl acetate occurs while preparing the solution or while performing the staining, the following procedures (TU Dublin Radiation Protection Guidance Notes for Working with Radiochemicals) must be followed;

1. If the powder is spilled while weighing, it will be caught in the tissue on the balance. Place this tissue in the waste bag.
2. If the liquid solution is spilled, an absorbent pad must be placed on the spilled liquid immediately.
3. Action should be taken to avoid the spread of contamination by restricting access to the contaminated area. The area must be cordoned off and a notice placed to warn other persons to keep clear of the area.
4. The School RPS and the RPO (City Campus) must be contacted immediately.
5. The spread of contamination, particularly on shoes or clothing of persons leaving the affected area, should be prevented. Persons who may be contaminated should be monitored immediately outside the area and appropriate arrangements made for their decontamination.
6. Contaminated clothing should be removed and left in or near the affected area. Contaminated parts of the body should be washed thoroughly but gently until either monitoring shows that contamination will not be significantly reduced further by this method or there is a risk of roughening or breaking the skin.
7. Any contaminated wound, however trivial, should be irrigated with water or saline solution, care being taken to limit any spread of contamination to or from other parts of the skin.
8. Persons entering the affected area to carry out emergency procedures should wear appropriate protective clothing which they should monitor and remove when they leave the area.

9. Access to the affected area should be restricted until radiation surveys show that the area may be reoccupied.
10. A Spill Kit containing disposable protective clothing, absorbent materials, decontaminating agents, warning signs, handling tools and receptacles for contaminated articles, will be available in the laboratory where the work is to be carried out.

Date of issue of SOP: 9th May 2012

Reviewed: 23th December 2022

Date of Review: December 2025 (Unless there is a change to procedures involved)

Signed:

Date:

3 SECTION – EMERGENCY OPERATING PROCEDURES AND CONTINGENCY PLANS

Names of Persons to be contacted

	Phone No Work	**Phone No Home/Mobile**
Jane Torris RPO (City Campus)	2205746	086-8930313
Dr. Cathal Flynn DRPO (City Campus)	2205716	
Dr. Elaine Doorly RPA		087-2644107
Dr. Maura Duffy (CREST)	4027897	
Prof. Fiona Lyng (RESC)	2205752	
Fire brigade	112	
Bridewell Garda station	01 666 8200	
TU Dublin Dean, Faculty of Sciences & Health	2205706 (J. Doran)	
TU Dublin Sciences & Health Manager	2205590 (E. Heffernan)	
Hospital, St Vincent's	2694533	
First Aid	087-9809135	
EPA	053-9160600/1890 335599	

Emergency Procedures

The Emergency Procedures in operation at present are contained within the TU Dublin Radiological Emergency Intervention Plan (see Appendix E).

The following are a range of emergencies or incidents which could occur involving sources of ionising radiation.

Event	Type of source(s)	Location of source(s)	Purpose of source(s)	Control measures	Likelihood of Event
Theft of sources	Sealed	CQ-123	UG teaching	1. Quarterly checks of sealed sources (presence, activity and condition of source) 2. The key for the safe in which the sealed sources are stored is secured in a coded safe with the access code issued to authorised staff only. 3. Standard operating procedure in place for use of sources which includes inventory control before and after laboratory sessions. 4. All Technical Officers are trained in the standard operating procedure to be used.	Very low.
Theft of sources	Sealed & unsealed (various)	CQ-123	Custody only	1. Double lock facility – sources stored in locked safes inside locked room. Swipe access control to laboratory door. 2. Only one keyholder for large floor storage safe present in CQ-123 (RPO (City Campus)). 3. Material present for custody purposes only and not in routine use. 4. Quarterly inventory of sources is carried out by RPO and DRPO.	Very low.
Loss of sources	Sealed	CQ-123	UG teaching	1. Quarterly checks of sealed sources (presence, activity and condition of source) 2. The key for the safe in which the sealed sources are stored is secured in a coded safe with the access code issued to authorised staff only.	Very low.

Event	Type of source(s)	Location of source(s)	Purpose of source(s)	Control measures	Likelihood of Event
				3. Standard operating procedure in place for use of sources which includes inventory control before and after laboratory sessions. 4. All Technical Officers are trained in the standard operating procedure to be used.	
Spillage or leakage	Unsealed (various)	CQ-123	Custody only	1. Only one keyholder for large floor storage safe present in CQ-123 (RPO (City Campus)). 2. Material present for custody purposes only and not in routine use. 3. Material in safes stored on plastic spill trays. 4. Quarterly inventory of sources is carried out by RPO and DRPO. 5. Quarterly wipe check of shelves in safes is carried out by RPO and DRPO.	Very low.
Spillage or leakage	Unsealed (Uranyl acetate salts)	FOCAS	PG Research	1. Standard operating procedure in place for use of sources. 2. All researchers are trained in the standard operating procedure to be used with this material. 3. All researchers using such material have completed a Radiation Safety Training course.	Low.
Accidental ingestion and/or inhalation	Unsealed (Uranyl acetate salts)	FOCAS	PG Research	1. Standard operating procedure in place for use of sources. 2. All researchers are trained in the standard operating procedure to be used with this material.	Very low.

Event	Type of source(s)	Location of source(s)	Purpose of source(s)	Control measures	Likelihood of Event
				3. All researchers using such material have completed a Radiation Safety Training course. 4. Stock solutions prepared in vented safety cabinets on paper-lined spill trays. 5. Sources used in low concentration working solutions. 6. Material use is monitored and logged by researchers.	
Deliberate ingestion and/or inhalation	Sealed	CQ-123	UG teaching	1. Sources are sufficiently large that accidental ingestion would be extremely unlikely and inhalation impossible. 2. The laboratory operates a 'nil by mouth' policy.	Extremely low.
Damage to source **or** source container	Sealed	CQ-123	UG teaching	1. Source containers are inspected monthly for presence of wear-and-tear by the school RPS. 2. Biannual wipe check of sources is carried out by RPO (City Campus)/DRPO (City Campus). 3. Material exhibiting noticeable wear-and-tear which threatens integrity of the sealed source is removed from use and replaced.	Low (evaluated on an ongoing basis)
Damage to source **or** source container	Unsealed (Uranyl acetate salts)	FOCAS	PG Research	1. Standard operating procedure in place for use of sources. 2. All researchers are trained in the standard operating procedure to be used with this material.	Low (evaluated on an ongoing basis)

Event	Type of source(s)	Location of source(s)	Purpose of source(s)	Control measures	Likelihood of Event
				3. All researchers using such material have completed a Radiation Safety Training course. 4. Defined amount of unsealed material present. 5. Use of material is monitored and logged by researchers.	
Theft of Equipment	X-ray unit (Leybold Didactic)	CQ-123	UG teaching	1. Restricted access to the CQ-123 as keys are only held by the technical officer in charge and security/buildings management staff.	Extremely low.
Theft of Equipment	X-ray units (XRD and XRF)	FOCAS (B.09.0 and B.18.0)	PG Research	1. Restricted access to the FOCAS site requiring card and keycode to access. 2. X-ray generator is permanently sited and not readily moveable.	Extremely low.
Accidental physical damage to instrument	X-ray unit	FOCAS	PG Research	1. Instrumentation is installed by trained technical staff and regularly maintained. 2. Instrument is present in a dedicated room and used only by trained operators.	Extremely low.
Malfunction, sabotage or deliberate misuse of instrument	X-ray unit	FOCAS	PG Research	1. Restricted access to the FOCAS site requiring card and keycode to access. 2. Instrumentation is installed by trained technical staff and regularly maintained. 2. Instrument is present in a dedicated room and used only by trained operators.	Extremely low.

Event	Type of source(s)	Location of source(s)	Purpose of source(s)	Control measures	Likelihood of Event
Combustion of source due to local fire	Sealed sources	CQ-123	UG teaching	1. All sources are stored within a lead-lined BriTec steel safe with outer casing thickness of approximately 1cm and total dimensions of 42 cm by 42 cm by 42 cm. Detailed specifications regarding fire resistance are unavailable for this safe but sustained fire will liquidise lead present and prevent direct combustion of sources. It is estimated that contents of the safe will be protected for 60-90 minutes. 2. Each source is stored in an individual lead pot. 3. Minor local fires will be acted on immediately to prevent damage to safe and/or stored sources. 4. Fire warden informed annually of location of sources on the Central Quad Grangegorman Campus. 5. In the event of complete combustion vaporisation of sources the overall contamination of the surfaces in the room (estimated total surface area of 3×10^6 cm^2) by the total stored radioactivity (2.3×10^6 Bq) will be less than 1 Bq/cm^2.	Unlikely.
Combustion and/or explosive	Sealed sources	CQ-123	UG teaching	1. All sources are stored within a lead-lined BriTec steel safe with outer casing thickness of approximately 1cm and total dimensions of 42 cm by 42 cm by 42 cm.	Very low.

Event	Type of source(s)	Location of source(s)	Purpose of source(s)	Control measures	Likelihood of Event
combustion due to campus-wide fire				Detailed specifications regarding fire resistance are unavailable but sustained fire will liquidise lead present and prevent direct combustion of sources. It is estimated that contents of the safe will be protected for 60-90 minutes. In the event of an explosion or building-wide high-intensity fire this safe is unlikely to protect the sources. 2. Fire warden informed annually of location of sources on the Central Quad Grangegorman Campus. 3. In the event of complete combustion, vaporisation and dispersal of all stored material (2.3×10^6 Bq) throughout the local access corridors and adjacent rooms will lead to an overall contamination of surfaces of significantly less than 1 Bq/cm^2. 4. Estimation of exposure to airborne material is difficult to quantify due to its dependence on environmental factors (e.g. prevailing winds, proximity to explosion) at the time of exposure.	
Combustion and/or explosive combustion due to campus-wide fire	Sealed & unsealed sources	CQ-123	Custody	1. All sources are stored within a large floor lead-lined steel safe with outer steel casing thickness of approximately 1cm and 2cm inner lead liner. Detailed specifications regarding fire resistance are unavailable for this safe but sustained fire will liquidise lead present in safe and prevent direct combustion of sources. It is estimated that contents of the safe will be protected for	Very low

Event	Type of source(s)	Location of source(s)	Purpose of source(s)	Control measures	Likelihood of Event
Combustion and/or explosive combustion due to campus-wide fire (Contd)				60-90 minutes. In the event of an explosion or building-wide high-intensity fire this safe may protect the sources, depending on the proximity to the explosion and fire. 2. Fire warden informed annually of location of sources on the Central Quad Grangegorman Campus. 3. In the event of a building-wide fire it is unlikely that the current building structures will restrict contamination to the storage room. In the worst case scenario of complete combustion, vaporisation and dispersal of all stored material throughout the local access corridors and adjacent rooms the estimated overall contamination will be approximately 15 Bq. 4. Estimation of exposure to airborne material is difficult to quantify due to its dependence on environmental factors (e.g. prevailing winds, proximity to explosion) at the time of exposure.	
Combustion and/or explosive combustion due to University wide fire	Sealed & unsealed sources	FOCAS	PG Research	1. Stored in CQ-123 2. Fire warden informed annually of location of sources on the Central Quad Grangegorman Campus.	Very low

4 SECTION – PLANNED MAINTENANCE PROCEDURES

4.0 Monitoring for Contamination and Planned Maintenance Procedures

This section provides an overview of the procedures which are undertaken routinely within the University to ensure that all areas where sources of ionising radiation are in use are free from contamination. Furthermore, this section provides a description of the procedures in place to ensure the safety of the sources of ionising radiation through the planned maintenance of such equipment.

4.1 Monitoring in the Workplace

Currently in TU Dublin no work involving unsealed sources of ionising radiation is carried out, therefore routine monitoring of the workplace is not required. However, if this type of work involving unsealed sources were to be carried out in a designated area the following monitoring procedures should be followed.

Suitable monitoring equipment must be obtained prior to starting work and must be available during the work period. If there is any doubt regarding the equipment to be used the School Radiological Protection Supervisor (RPS) or the Radiological Protection Officer must be consulted. Suitable portable monitors are available in schools to enable staff to assess levels of radiation exposure and radioactive contamination. These instruments are checked regularly by the RPS and must be kept in operational condition and used at all times when work with ionising radiation is in progress. Any functional defect in a monitor must be reported to the RPS. For some low energy beta emitters, the only satisfactory method of contamination monitoring may be wipe testing.

The following points should be borne in mind:

(a) During active handling operations (e.g. fume cupboards or glove boxes) monitoring should be carried out frequently as work proceeds, and at the end of a working session prior to leaving the laboratory;

(b) Gloved hands and laboratory coats and other parts which might become contaminated must be monitored.

4.2 Wipe-Testing of Sealed Sources

All sealed sources must be wipe-tested at least once every 24 months or more frequently dependent upon the conditions and usage to which the source is subject. In the event of suspected damage to any source or its housing, a leakage test must be immediately undertaken by the RPO (City Campus)/DRPO (City Campus). The following procedure for the wipe test is used as per the EPA guidance document:

(a) Wear disposable gloves when performing wipe tests to minimise the spread of contamination from surfaces wiped to fingers;

(b) use 2cm x 2cm diameter filter paper, moistened with alcohol (i.e. Sterets Pre-Injection Swabs Stock No. 00766691 are recommended by the EPA);
(c) apply light pressure to the swab, contacting 100cm^2 (10cm x 10cm square) of the surface to be tested;
(d) each wipe sample should be counted with an assay system sensitive to the isotopes used in the area tested.
(e) surfaces for which wipe test results exceed 185 DPM/100cm^2 must be immediately decontaminated and re-wipe tested;
(f) above must be repeated as necessary until wipe test results are less than 185 DPM/100cm^2.

4.3 Maintenance Procedure for Apparatus Capable of Producing Ionising Radiation

Licensed sources of Ionising Radiation must be checked for correct operation at least once in every 12-month period (by suitably qualified individuals in accordance with the manufacturer's instructions). Records of such maintenance must be forwarded to the RPO (City Campus)/DRPO (City Campus) for collation. In the event of substantial change to a part of a licensed item (e.g. repair or replacement of parts of a device emitting ionising radiation), this change must be verified for correct operation, and evidence for same forwarded to the RPO (City Campus)/DRPO (City Campus), prior to the licensed item resuming its normal use. Records of such maintenance and servicing procedures are to be retained by the responsible School or Research Group. The results from the servicing and safety checks should be forwarded to the RPO (City Campus) for presentation at the first RPAC meeting of the academic year (typically in late October or early November).

5 SECTION – RADIOLOGICAL SAFETY PROCEDURES

5.1 Classification of Workers Undertaking Work Involving Sources of Ionising Radiation

5.1.1 Exposed Workers

An 'Exposed Worker' is defined as a person likely to receive an exposure liable to result in a radiation dose that exceeds one or other of the dose limits for public exposure, i.e. an effective dose in excess of 1mSv per year. Category A exposed workers are liable to receive an effective dose of greater than 6mSv in 12 months or an equivalent dose greater than 15mSv per year for the lens of the eye, or greater than 150mSv per year for skin and extremities. Category B exposed workers are liable to receive an effective dose greater than 1 mSv but less than 6 mSv in a year or an equivalent dose not greater than 15 mSv per year for the lens of the eye, or greater than 50 mSv but less than 150 mSv per year for skin and extremities. It is unlikely that any individual currently working at TU Dublin will receive a radiation dose in excess of 1mSv per year. Personal dosimetry monitoring is therefore not required for any individual at present.

5.1.2 Authorised Radiation Workers

Radiation work is restricted to those who have been authorised by the RPAC. Authorisation will be granted only if the following conditions are satisfied.

- Workers must have attended the appropriate training as outlined in the Training Policy. Those who have previous experience of work with ionising radiations may be exempt from parts of the training but must present evidence of training and copies of any previous dose record(s) to the RPAC.
- A proposed application of the work involving sources of ionising radiation must be submitted on the appropriate form to the RPO (City Campus) who will present it to the RPAC as outlined in Section 2.2. The proposal must be countersigned by the RPS after verifying that the worker has been instructed in the techniques to be used and understands the hazards involved and the precautions to be observed. If satisfactory, the RPAC will approve the application and send it to the EPA for approval. If the EPA approve the proposed work any radiation monitoring or other necessary conditions will be put in place in conjunction with the School or Research group.

5.1.3 Pregnant or Breastfeeding Workers (see Appendix D for Guidelines)

5.1.3.1 Legal Requirements

Once a pregnancy is confirmed the dose to the foetus must not exceed 1mSv for the rest of the pregnancy. This is regardless of whether the worker is monitored with dosimeters or not. It is however difficult to determine the actual dose to a foetus, therefore the approach of monitoring the exposure of the worker to radiation will ensure that the foetal dose is measured using the radiation dosimeters for the duration of the pregnancy and that it does not exceed 1mSv. The annual dose to an infant must be limited to not more than 1mSv per year. In most cases there should be no need to restrict work with radioactive materials as the doses received are unlikely to approach the permitted limit, but occasionally it may be considered prudent for a pregnant worker to curtail a particular aspect of their work e.g. radioiodinations.

It is the Employers (i.e. TU Dublin) responsibility to manage the control of radiation exposure of its employees and other persons. The law is however quite clear that if a pregnant worker does not tell her employer that she is pregnant, the employer is not required to introduce any special measures.

5.1.3.2 Controls

The following control measures should be applied when TU Dublin has been informed that a worker is pregnant. To ensure that the risk to the expectant mother or to the foetus is minimised, pregnant workers must inform their Line Manager, in writing, that they are pregnant as soon as possible.

Once the Line Manager has been informed, they will then arrange a review of the relevant radiation risk assessment. This should be done in conjunction with TU Dublin's Radiation Protection Officer (RPO (City Campus)) or Deputy Radiation Protection Officer (DRPO (City Campus)). As part of the review, any relevant dose records for the pregnant worker will be checked.

The review of the risk assessment should identify and record any changes or restrictions to work practices that are required to meet the special dose limit. These will be communicated back to the expectant mother within two weeks of the RPAC being informed of the pregnancy. It is important that she co-operated with her Line Manager in complying with any of these changes or restrictions and seeks further advice from TU Dublin's RPO (City Campus) or DRPO (City Campus) if unsure about anything.

5.1.3.3 Exposure to External Radiation Only

This applies to exposure arising from radiation sources such as sealed sources, undergraduate experimental X-ray systems and analytical X-ray sources. The following guidelines apply to such exposure:

- If the worker is working in an area designated as Supervised due to the external radiation risk, then work may continue and (if not already the case) she should wear a whole-body personal dosimeter (four-weekly wearing period) for the duration of the work with radiation whilst pregnant.
- Currently any work involving sources of ionising radiation within TU Dublin produce a total exposure less than the 1mSv limit and so no additional controls of restrictions should be necessary for pregnant workers and breastfeeding mothers.

5.1.3.4 Minimising external radiation exposures

The fundamental ways of reducing external radiation exposure are:

(i) Limiting the activity of the source (or energy of the X-rays) used.
(ii) Placing shielding around the source
(iii) Maintaining sufficient distance from the source. Operate the inverse square law concept in which the intensity of the dose is inversely proportional to the square of the distance.
(iv) Reducing the time of exposure if (i) to (iii) are not feasible

The latter option, in particular, necessitates the use of a dose-rate meter and an understanding of the units of dose and dose limitation.

5.2 Designated Areas

Radiation work is permitted only in areas which have been approved by the RPAC for the purpose. When plans are being made for any new radiation area or modification to an existing area the RPAC must be informed through the RPO (City Campus).

At the entrance to each area, a sign will be posted indicating the designation of the area, the nature of the source and any restriction of activities in use. Also listed are the names of authorised workers and those responsible for supervision of work in the area.

The Regulations specify two categories of area for radiation work, namely Controlled and Supervised Areas, determined by the likely radiation dose of those working in the areas. For each school, the Controlled and Supervised Areas will be listed in the local rules.

5.2.1 Controlled Area

A Controlled area is where it is necessary to follow special procedures to restrict exposures which will exceed 6mSv per year or an equivalent dose greater than 15mSv per year for the lens of the eye or greater than 150mSv per year for skin or extremities. The dose might be due to external radiation or internal contamination or a combination of both. In most schools using unsealed radionuclides there will be one Controlled Area for the storage and dispensing of stock materials.
A Controlled Area for the use of unsealed sources is identified by a yellow certificate carrying the radiation trefoil symbol. The laboratory should be fitted with impervious working surfaces and continuous, easily cleaned flooring, gloss painted walls and ceiling and contain a fume cupboard dedicated to radioactive use. High activity material may be stored, dispensed and processed by authorised workers only.

5.2.2 Supervised Area

An area in which effective doses could exceed 1mSv per year and/or where working conditions need to be kept under review to ensure that designation as a controlled area is not required should be designated a Supervised Area. In some circumstances, radiation areas in schools may be Supervised areas which are parts of laboratories used for other purposes. Areas in the laboratory where radioactive materials are used, or are in storage, must be clearly marked with notices bearing the radiation trefoil symbol.

5.2.3 Other Areas

In areas other than Controlled or Supervised Areas, only low level procedures may be carried out by arrangement with the RPS. Activity and radiation dose levels must be well below those which apply to a Supervised Area. An example would be a room used for sample counting or a class laboratory where very low activities are used in demonstrations or experimental work. Most radiation areas in schools will normally be in this category of Other Areas which may be parts of laboratories used for other purposes.

5.3 Access to Controlled Areas

The Regulations require that access to a Controlled Area is restricted to either classified persons or those working under a written system of work which will ensure that dose levels are acceptable. Systems of work for particular procedures can be found in school local rules. For authorised workers, the Scheme of Work Application Form must include details of the areas in use and means of limiting dose such as maximum permitted activities, use of shielding and other protective measures. For other workers such as cleaning staff, Works Division staff, service engineers and others, entry will be under the supervision of an authorised worker who will ensure that sources are returned to shielded positions and accessible surfaces are decontaminated.

5.4 Dose Rates

In radiation areas, as already noted, all exposures should be kept as low as reasonably achievable. There are many ways of ensuring this, such as the use of shielding materials, reducing times of exposure and keeping sources and workers apart. For this reason, it is not possible to specify acceptable dose rates. However, the Regulations make it clear that dose rates in excess of 7.5 microsieverts per hour should occur only in Controlled Areas, and dose rates between 2.5 and 7.5 microsieverts per hour are appropriate to Supervised Areas. In other places, including public areas, doses should be below 2.5 microsieverts per hour.

5.5 Personal Radiation Monitoring

Any authorised staff worker exposed to significant levels of radiation from X-rays, gamma radiation, hard beta radiation or neutrons (and who is likely to receive a radiation dose in excess of 1mSv per year) will be required to wear a personal dosimeter to assess exposure. It may be necessary to measure whole body dose or dose to a part of the body such as the fingers and a film badge or thermoluminescent monitor may be used.

Dosimeter use in TU Dublin for staff and/or students is currently not warranted. It is indicated by Risk Assessment (see Appendix F) that no staff or students are expected to receive doses in excess of 1 mSv per annum.

If there are requirements for biological monitoring, this will be specified in the scheme of work and the RPS will advise on the local arrangements in each school.

5.6 Calibration of Monitoring Equipment

Suitable portable monitors are available in the School of Physics to enable staff to assess levels of radiation exposure and radioactive contamination. These instruments are checked regularly by the RPO (City Campus) and must be kept in operational condition and used at all times when work with ionising radiation is in process. Any functional defects in a monitor must be reported to the RPO (City Campus).

All meters for measuring dose rates, count rates and contamination at the University must be calibrated once a year by an accredited laboratory. Records of these calibrations are held by the RPO (City Campus) (and copies thereof must be provided to the RPO (City Campus) if held by Heads of School / Centre Managers).

6 SECTION – ADMINISTRATION

Administration of manuals

Holders of Controlled Copies of the TU Dublin Radiological Safety Manual.

Each named holder of a controlled copy of the TU Dublin Radiological Safety Manual has a responsibility to implement the policies and procedures contained in this manual, to ensure that no unauthorised copies of the manual are produced, and that all suggestions for amendment are forwarded to the RPO (City Campus).

Related Documents

TU Dublin Safety Statement

EPA Licence Conditions

National Regulations and Statutory Instruments

LIST OF CONTROLLED COPIES:

Listed below are the names and copy number of holders of controlled copies of the TU Dublin Radiological Safety Manual.

Names	**Copy No.**
Chair of TU Dublin Radiation Protection Advisory Committee,	
Professor John Doran	1
Jane Torris, RPO (City Campus)	2
Dr Cathal Flynn, Deputy RPO (City Campus)	3
CREST Research Centre, FOCAS Research Institute	4
RESC Research Manager, FOCAS Research Institute	5
School of Physics, Clinical and Optometric Sciences	**6-10**

6.0 Objective

The Objective of this Safety Manual is to ensure that TU Dublin Campuses conforms to best safety practice in the use of Sources of Ionising Radiation and observe the terms and conditions of the licence issued by the Environmental Protection Agency.

6.1 Scope

This Safety Manual applies to all authorised staff and researchers who are required to use Sources of Ionising Radiation as part of their duties on behalf of TU Dublin.
To deal with this matter the Safety Manual sets out the organisation, the duties, authority and responsibility of TU Dublin personnel who are named in the document. This Manual sets out the means by which the Technological University Dublin Campuses will manage, organise and control the use of Sources of Ionising Radiation on its premises. This involves the Directors, Heads of Schools, Centre

Managers and authorised staff involved in the use of Ionising Radiation in TU Dublin.

The Safety Manual sets out in a reasonable practicable way the safety, health and welfare requirements that must be observed by those using Sources of Ionising Radiation in order to prevent injury or ill health to authorised staff, postgraduates or undergraduate students.

Technological University Dublin is committed to providing the necessary resources to ensure a safe place of work, safe equipment and the training necessary to carry out the tasks in a competent manner.

Under S.I. No. 30 of 2019 TU Dublin is required to have a licence to regulate the acquisition, custody, use, transportation and disposal of Sources of Ionising Radiation. The following sections are designed to meet this requirement and to foster the highest standards of safety and care. Detailed sections applicable to each type of Sources of Ionising Radiation found in TU Dublin are included. The use of Sources of Ionising Radiation in TU Dublin is controlled by a number of Acts and official regulations.

The most important of these are:

a) Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019, Statutory Instrument No. 30 of 2019
b) Council Directive 2013/59/EURATOM Laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation (Basic Safety Standards Directive).
c) Any regulations and guidance notes that may be issued by the Environmental Protection Agency – Office of Radiological Protection.
d) Safety, Health and Welfare at Work Act 2005.

The provisions of these rules may be supplemented or modified by the licence from the EPA's Office of Radiological Protection (An Institiúid Éireannach Um Chosaint Raideolaioch). A copy of the current licence is on display in relevant locations within the University.

Signed: _____ Date:_____

Professor John Doran

Chair Radiation Protection Advisory Committee, Technological University Dublin

6.2 The RPO (City Campus) and The Environmental Protection Agency – Office of Radiological Protection (EPA)

The Radiation Protection Officer communicates, on behalf of the University, with the EPA in regards to all issues pertaining to the University's licence. The duties and responsibilities of the RPO (City Campus) are outlined in the EPA Guidance Document (June 2000) available from the EPA website at http://www.epa.ie/pubs/advice/radiation/guidancenotesontheroleoftherpo.html and under Regulations 34 and 80 of S.I. No. 30 of 2019.
The duties of the Deputy RPO may be considered to be identical at all times.

6.3 Radiation Protection Advisory Committee (RPAC)

Ionising radiation in the workplace is regulated by the Radiological Protection Act, 1991 (Ionising Radiation) Regulations 2019 (Statutory Instrument No. 30 of 2019). The Order applies to all practices which involve a risk of exposure to ionising radiation. Under this Order the EPA's Office of Radiological Protection has responsibility for licensing and regulating sources of ionising radiation. This agency issues a licence to Technological University Dublin and has defined the duties and responsibilities of the Radiation Protection Advisory Committee which administers the licence. These responsibilities include ensuring that all persons involved in the handling of sources of ionising radiation have adequate training and experience enabling them to perform their duties safely and in accordance with the licensee's radiation safety program and EPA requirements. Furthermore, the committee is required to ensure that equipment and facilities used with radiation sources are in compliance with EPA requirements.

In general terms: The staff permitted by the RPAC to work with sources of ionising radiation are personally responsible for radiation safety in all the areas specified in their Standard Operating Procedures; users of ionising radiation are personally responsible for the safe handling of radioactive materials and equipment capable of producing ionising radiation, and the Radiation Safety Officer is responsible for coordinating and overseeing all aspects of radiation safety within the University.

The TU Dublin University Radiation Advisory Committee administers and advises on all matters relating to radiation safety within TU Dublin, in particular on the Grangegorman Central Quad and the FOCAS Research Institute. TU Dublin City Campus, Central Quad Grangegorman, and the FOCAS Research Institute are the only centres within the University at which activities of a radiological nature take place, thus the committee comprises personnel from within the Faculty of Sciences and Health and its associated research centres. Figure 6.1 indicates the lines of communication and authority in relation to radiation protection within TU Dublin.

The Committee is responsible for ensuring that safe practices are established and maintained, and is in compliance with the EPA guidelines and licence conditions, and will issue regulations to that effect. It reports to the Director of the College of Sciences and Health who is the Chair of the Radiological Protection Advisory Committee.
The Committee is composed of the Radiation Protection Officer, Deputy Radiation Protection Officer and School (or Centre) Radiological Protection Supervisors (SRPS) together with Research and Administrative Authorised staff and reflects the areas in which activities which utilise ionising radiation occur within TU Dublin.

Committee (as of February 2023):
Prof. John Doran (Chair of the Radiation Protection Advisory Committee)
Jane Torris (City Campus Radiation Protection Officer)
Dr Cathal Flynn (City Campus Deputy Radiation Protection Officer)
Prof. Fiona Lyng (RPS, Centre Manager, RESC, FOCAS)
Maura Duffy (RPS, Quality Manager, CREST, FOCAS).

Technological University Dublin Radiation Protection Advisory Committee and Organisational Structures in relation to Radiological Protection

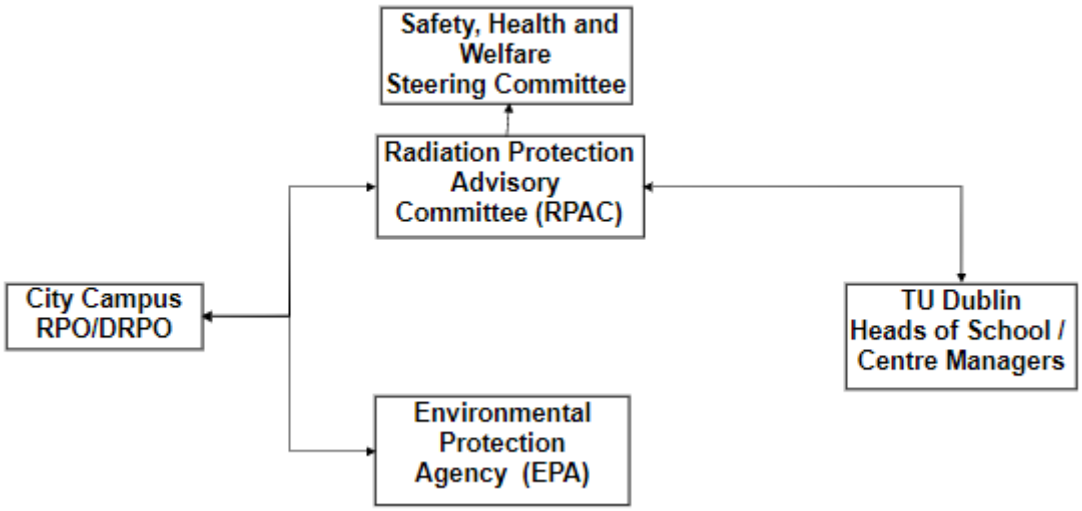


Fig. 6.1: Flow chart of communication lines in relation to radiation protection

Health & Safety Teams

Health & Safety Teams report into the DIT SLT Health & Safety Sub-Committee

HUMAN RESOURCES & FINANCE & RESOURCES

Chair: Director of HR & Director Finance & Resources to rotate annually

Members:

Representatives as follows:-

- Designated Buildings Officer
- Designated Building Service Supervisor
- Designated Occupational Health Officer
- Staff Training and Development Officer
- Nominee from Research & Enterprise
- Nominee from Information Services
- Nominee from Academic Affairs & Registrar
- Learning, Teaching & Technology Centre
- An Elected Staff Representative

Buildings in Scope:

143-149 Rathmines ; Mount Street

STUDENT SERVICES

Chair: Director of Student Services

Members:

- *Representatives from each of the following functions:-*
  - Student Administration
  - Campus Life
  - Community Links
  - Philanthropy
  - Campus Planning
  - International Office
- Senior Manager in Student Services
- An Elected Staff Representative
- An Elected Student Representative
- Buildings Maintenance Manager(s)
- Building Service Supervisor (s)
- Designated Occupational Health Officer

Buildings in Scope:

- Grangegorman; 23 Mountjoy Square; Bannow Rd

ACADEMIC AFFAIRS & REGISTRAR

Chair: Director of Academic Affairs & Registrar

Members:

- *Representatives from each of the following functions:-*
  - Academic Records and Quality Assurance
  - Enrolment Planning and Admissions
  - Library Service
- Senior Manager in Academic Affairs & Registrar
- An Elected Staff Representative
- An Elected Student Representative
- Designated Occupational Health Officer

COLLEGE OF ARTS & TOURISM

Chair: Director & Dean of College of Arts & Tourism

Members:

- *Representatives from each of the following functions:-*
  - Conservatory of Music and Drama
  - School of Art Design and Printing
  - School of Culinary Arts and Food Technology
  - School of Hospitality Management & Tourism
  - School of Languages
  - School of Media
  - School of Social Sciences & Law
  - CSER; CTMP; DMC
- College Manager /Senior Functional Manager
- An Elected Staff Representative
- An Elected Student Representative
- Buildings Maintenance Manager(s)
- Building Service Supervisor(s)Designated Occupational Health Officer

Buildings in Scope:

- Cathal Brugha Street; Chatham Row;
- Marlborough Street; 40-45 Mountjoy Sqaure; Portland Row; 169 Rathmines; Sackville Place; Temple Bar

COLLEGE OF BUSINESS

Chair: Director & Dean of College of Business

Members:

- *Representatives from each of the following functions:-*
  - School of Accounting & Finance
  - School of Management
  - School of Marketing
  - School of Retail & Services management
  - Graduate School of Business
- College/Senior Functional Manager
- An Elected Staff Representative
- An Elected Student Representative
- Buildings Maintenance Manager(s)
- Building Service Supervisor(s)
- Designated Occupational Health Officer

Buildings in Scope:

- Aungier Street

COLLEGE OF ENGINEERING & BUILT ENVIRONMENT

Chair: Director & Dean of College of Engineering & Built Environment

Members:

- *Representatives from each of the following functions:-*
  - School of Architecture
  - School of Civil & Building Services Eng (DEL)
  - School of Construction
  - School of Electrical Engineering Systems
  - School of Electronics & Communications Eng (CNRI, PRC, AHFR)
  - School of Manufacturing & Design Eng (CER)
  - School of Mechanical & Transport Eng
  - School of Real Estate & Construction Econ
  - School of Spatial Planning
  - DEL; CNRI; PRC; AHFR; CER
- College/Senior Functional Manager
- An Elected Staff Representative
- An Elected Student Representative
- Buildings Maintenance Manager(s)
- Building Service Supervisor(s)
- Designated Occupational Health Officer

Buildings in Scope:

- Beresford Street; Bolton Street; Green Street; Linenhall; Lurgan Street; 81 Capel Street; Slaney Rd, Airport Business Park

COLLEGE OF SCIENCES & HEALTH

Chair: Director & Dean of College of Sciences & health

Members:

- *Representatives from each of the following functions:-*
  - School of Biological Sciences
  - School of Chemical & Pharmaceutical Sciences (Crest)
  - School of Computing
  - School of Food Science & Env Health
  - School of Mathematical Sciences
  - School of Physics (IEO, RESC, NOC)
- College/Senior Functional Manager
- An Elected Staff Representative
- An Elected Student Representative
- Buildings Maintenance Manager(s)
- Building Service SupervisorDesignated Occupational Health Officer

Buildings in Scope:

- Church Lane; Kevin Street; NOC, Lower Kevin Street; New Bride Street;

RESEARCH AND ENTERPRISE

Chair: Director of Research & Enterprise

Members:

- *Representatives from each of the following functions:-*
  - Graduate Research School
  - Research Development
  - Research Support & Project Mnagement
  - Research Finance
  - Hothouse
  - FOCAS
- Senior Manager in Research & Enterprise *
- An Elected Staff Representative
- Buildings Maintenance Manager(s) Building Service Supervisor
- Designated Occupational Health Officer

Buildings in Scope:

- FOCAS; Docklands Innovation Park;

Radiation Protection Advisory Committee

Chair: President or Nominee

Members:

- Radiation Protection Officer (RPO)
- Deputy Radiation Protection Officer (DRPO)
- Radiation Protection Supervisor (RPS) for each School, Depart or centre carrying out work involving sources of ionising radia
- Any staff member actively working with sources of ionising ra

Buildings in Scope:

- All DIT buildings and premises

6.4 Chair of the Radiation Protection Advisory Committee
CHAIR: - Professor John Doran

6.4.1 Authority
The RPAC Chair has the authority to manage and control the safe use of all Sources of Ionising Radiation on TU Dublin premises.

6.4.2 Responsibility
To ensure that Heads of Schools and Centre Managers conform and apply the controls as laid down in the Safety Manual and on the safe use of Sources of Ionising Radiation as required by the EPA licence.

6.4.3 Duties
- To ensure the Safety Manual is maintained and kept up to date with legislation and appropriate regulations.
- To ensure the University Radiation Advisory Committee meets at least twice a year and that those copies of the minutes and reports are forwarded to the members.
- To ensure that the TU Dublin Licence is up to date and displayed as required in an appropriate public areas.
- To arrange for a biennial audit of the Safety Manual and to revise the Safety Manual if the need arises.

6.5 Radiation Protection Officer (RPO/DRPO)
RPO (City Campus) - Jane **Torris**

City Campus Deputy RPO - **Dr. Cathal Flynn**

6.5.1 Authority:
The RPO (City Campus) communicates with the EPA, on behalf of the University and the RPAC, on all aspects of the Radiation Licence and acts to ensure that the University is at all times compliant with its licensing conditions. The RPO (City Campus) has, on behalf of the University, the authority to implement changes to University regulations, practices and licensing of practices involving sources of Ionising Radiation in conjunction with the RPAC and in consultation with the EPA. The RPO (City Campus) and DRPO are appointed by the Governing Body of TU Dublin subject to EPA approval.

6.5.2 Responsibility:
The Radiation Protection Officer is responsible for assisting TU Dublin in order that it complies with the terms and conditions of the licence granted by the EPA's Office of Radiological Protection. Ultimate responsibility for compliance rests with the University as the Licensee.

The RPO (City Campus) and DRPO (City Campus) oversee radiological protection for Grangegorman, Aungier Street, Bolton Street and the Focas Research Institute. Their duties do not include the Blanchardstown Campus or Tallaght Campus.

6.5.3 Duties:

The RPO may have specific tasks, depending on the nature of the practice as outlined in Regulation 34 of SI 30 of 2019. These are detailed below:

(a) ensuring that work with radiation is carried out in accordance with the requirements of any specified procedures and working instructions;
(b) supervising the implementation of the programme for workplace monitoring;
(c) maintaining adequate records of all radiation sources;
(d) carrying out periodic assessments of the conditions of the relevant safety and warning systems;
(e) supervising the implementation of the personal monitoring programme;
(f) supervising the implementation of the health surveillance programme;
(g) providing new workers with an appropriate introduction to specified procedures and working instructions;
(h) giving advice and comments on work plans;
(i) establishing work plans;
(j) providing reports to the local management;
(k) participating in the arrangements for prevention, preparedness and response for emergency exposure situations;
(l) information and training of exposed workers; and
(m) liaising with the radiation protection adviser.

In practice at TU Dublin the RPO is required to undertake the following duties to ensure that radiological safety compliance is managed effectively at the University:

- To liaise with and inform the RPAC Chair and Heads of Schools on all matters affecting the safe use of Sources of Ionising Radiation in TU Dublin.
- To maintain and update the TU Dublin Radiological Safety Manual in co-operation with the EPA.
- To ensure that the University RPAC meets at least twice a year or as often as required.
- To report to the RPAC on the outcome of its decisions, for information purposes only.
- To ensure that appropriate safety training and/or supervision is provided for authorised staff that are required to use Sources of Ionising Radiation and related equipment.
- To maintain all dosimeter records of authorised staff using radiation sources.
- To provide necessary calibrated screening tools for Ionising Radiation within the University.

- To inform the EPA's Office of Radiological Protection of any accident or incident involving the use of Sources of Ionising Radiation in TU Dublin on behalf of TU Dublin, and in conjunction with the Chair of the Radiation Protection Advisory Committee and President of TU Dublin.
- To arrange medical screening biennially for authorised staff using radiation sources where appropriate.
- To investigate any accident or incident involving the use of Sources of Ionising Radiation within TU Dublin.
- To report incidents or accidents to the President of the University and the Chair of the Radiation Protection Advisory Committee.
- To ensure that the TU Dublin licence is current and displayed as required in an appropriate public area.
- To ensure that a list of authorised users of Sources of Ionising Radiation is maintained in each licensed location.
- To perform regular (quarterly) checks of the Sealed and Unsealed radioactive material in use or storage on the TU Dublin.
- To ensure that the use of sources of Ionising Radiation within the University complies with the relevant legal provisions and with EPA guidance.

TU Dublin shall provide the radiation protection officer, with adequate information and facilities for him/ her to discharge their functions.

6.6 Radiation Protection Adviser (RPA)

RPA - **Dr. Elaine Doorly**,

Radiation Safety Ireland,

087-2644107

elaine@radiationsafety.ie

www.radiationsafety.ie

A Radiation Protection Adviser (RPA) is appointed to liaise with the RPO (City Campus) and to provide advice and guidance as necessary. The RPA is appointed in accordance with Regulation 33 of the Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019

The RPA will undertake an annual site visit and an annual radiation safety training course on site.

6.6.1 Duties:

Regulation 33 of SI 30 of 2019 requires the undertaking to seek advice from a radiation protection adviser and shall provide the radiation protection adviser with access, adequate information and facilities for the discharge of his or her functions in relation to the following: –

(a) the examination and testing of protective devices and measuring instruments;

(b) the prior critical examination of plans for installations from the point of view of radiation protection;

(c) the acceptance into service of new or modified radiation sources from the point of view of radiation protection;

(d) the regular checking of the effectiveness of protective devices and techniques;

(e) the regular calibration of measuring instruments and the regular checking that they are serviceable and correctly used.

The advice of the radiation protection adviser shall cover, where relevant, but not be limited to, the following: –

(a) optimisation and establishment of appropriate dose constraints;

(b) plans for new installations and acceptance into service of new or modified radiation sources in relation to any engineering controls, design features, safety features and warning devices relevant to radiation protection;

(c) categorisation of controlled and supervised work areas;

(d) classification of workers;

(e) workplace and individual monitoring programmes and related personal dosimetry;

(f) appropriate radiation monitoring instrumentation;

(g) quality assurance;

(h) environmental monitoring programme;

(i) arrangements for radioactive waste management;

(j) arrangements for the prevention of accidents and incidents;

(k) preparedness and response in emergency exposure situations;

(l) training and retraining programmes for exposed workers;

(m) investigation and analysis of accidents and incidents and appropriate remedial actions;

(n) employment conditions for pregnant and breastfeeding workers; and

(o) preparation of appropriate documentation such as prior risk assessments and written radiation safety procedures.

Upon consultation with a radiation protection adviser or advisers, the undertaking shall devise and submit to the Agency as part of a licence application, renewal or amendment, the agreed arrangements with the named radiation protection adviser detailing the provisions that are in place to meet the requirements of these Regulations.

6.7 School/Centre Radiological Protection Supervisors (RPS)

6.7.1 Responsibilities:

School/Centre Radiological Protection Supervisors shall have responsibility for the supervision of the safe use and operation of Sources of Ionising Radiation in their School / Centre in compliance with the terms and conditions of the TU Dublin licence and on behalf of their Head of School / Centre Manager. Ultimate responsibility for the safe use and operation of Sources of Ionising Radiation in any School / Centre is the responsibility of the Head of School / Centre Manager.

6.7.2 Duties:

- To ensure, by means of regular inspection, that authorised staff implement the TU Dublin Radiological Safety Manual.
- To maintain all records as are required by the TU Dublin Licence.
- To ensure that authorised staff are familiar with and have copies of the emergency procedures in relation to radiological protection.
- To ensure that no member of staff who has not been trained is allowed to use such equipment until adequate training has been provided by TU Dublin.
- To ensure that a register is kept of all Sources of Ionising Radiation those are used within the school / centre.
- To ensure that the required radiation surveys are carried out in compliance with the terms of the TU Dublin licence and are recorded by the person authorised to do so.
- To inform the Head of School/Centre Director and Radiation Protection Officer in writing of any incident or accident relating to Sources of Ionising Radiation within the school /centre.
- To investigate, if necessary, a member of authorised staff in their school / centre to ensure that the appropriate dosimeter badge is being worn for the equipment in use.

6.8 Heads of Schools and Centre Managers

6.8.1 Responsibilities:

Heads of Schools and Centre Managers are responsible for ensuring that equipment, facilities and sources of ionising radiation are maintained in compliance with the TU Dublin licence and the TU Dublin Radiological Safety Manual. They are also responsible for the safe use and operation of Sources of Ionising Radiation in their School / Centre in compliance with the terms and conditions of the TU Dublin licence.

6.8.2 Duties:

- To ensure that each person using radiation sources in their school / centre is trained in the safe practices and procedures in relation to the sources in use or to be used.
- Ensure that each authorised staff member is fully acquainted with all the emergency procedures when using the equipment/sources.
- Keep a register of all radiation sources in their school together with periodic contamination leakage checks carried out on the sealed sources by themselves or members of authorised staff.
- Make the register available to the Radiation Protection Officer or any officer from the EPA's Office of Radiological Protection or Health and Safety Authority on request.
- Inspect and check all registers and log books pertaining to the equipment in their school at least twice a year.
- Liaise with the School / Centre Radiological Protection Supervisor in relation to instructions of the EPA.
- Carry out inspections of equipment, sources and procedures with the School/Centre Radiological Protection Supervisors at least once annually year as appropriate and report the outcome of this to the RPO/DRPO.
- Provide for the safe storage of all sources of Ionising Radiation within their School/Centre.
- Ensure that they are informed of any incident or accident involving authorised staff or equipment by their RPS as soon as possible.
- Review the total operation with the School / Centre Radiological Protection Supervisor once a year to ensure compliance with the TU Dublin Licence and its Safety Manual and report the outcome of this to the RPO/DRPO.

6.9 Authorised Staff

6.9.1 Responsibilities:

Each individual in the University working with ionising radiation is legally responsible for taking due care for their own health and safety and the health and safety of anyone under their supervision or who may be affected by their work activities involving ionising radiation.

6.9.2 Duties

- To be personally responsible for the wearing and maintenance of his/her radiation badge when using any source of ionising radiation where it has been deemed necessary by the RPO /DRPO to wear such a radiation badge. This duty is not deemed necessary under current working conditions as no dose rate will exceed 1mSv per annum.
- To ensure that they are familiar with the practices and procedures (including appropriate emergency procedures) for the use of any source of ionising

radiation with which they have been authorised (by the University RPAC) to work.

- To ensure that postgraduate / postdoctoral research work is supervised to comply with the TU Dublin Radiological Safety Manual.
- To complete the form at the end of the Safety Manual, stating that they are familiar with and understand the operations and emergency procedures appropriate to the equipment and sources that they are to use before commencing work.

6.10 Staff Radiation Awareness Training Policy

As per Regulation 35 of Statutory Instrument 30 of 2019, each user of radioactive material or radiation producing equipment will attend a One Day, Radiation Safety Course prior to beginning unsupervised work. This one day radiation safety course will cover the following topics: Basic Concepts in Radiological Protection, Health Effects of Ionising Radiation, Principles of Protection from External & Internal Radiation, X-ray Safety, Compliance with Legislation and Licensing Procedures, X-ray Safety, Emergency Procedures, Radiation Safety Procedures, Risk Assessments and the role of the Radiation Protection Officer. A multiple-choice written examination will be held at the end of the course and certificates of achievement/attendance will be issued to all candidates. Each user of radioactive material or radiation producing equipment will undertake a ½ day refresher radiation safety training course every 3 years.

6.10.1 Orientation

All new staff or users of radioactive material or radiation producing equipment must obtain training on the next available course date.

Where induction occurs between training dates, training for each user will also be provided in the laboratory by an experienced user designated by the Head of School or Principle Investigator. Topics covered during this training will include the following, where appropriate

- Safe use of laboratory equipment and materials, including personal protective equipment
- Standard Operating Procedures and experimental protocols, including operating procedures for radiation producing machines
- Safe Handling, storage and disposal of radioactive materials
- Proper maintenance of required records
- Methods to control and measure radiation levels and contamination
- Emergency procedures

Each individual working with sources of ionising radiation in the University are obliged to familiarise themselves with and to comply with the conditions of the University's Radiation licence and the University's Radiation Safety Procedures described within this Radiation Safety Manual. All individuals working with ionising

radiation are obliged to consult the University's RPO (City Campus)/DRPO (City Campus) before undertaking any work with ionising radiation, and as necessary during the course of their work.

Regulation 35 (1) and (3) of S.I. No. 30 of 2019 deals with "Radiation Protection Education, Training and Information". The specific regulation is as follows:

35. (1) Every undertaking, and in the case of outside workers, the employer, must ensure that:-

a) all exposed workers, apprentices and students who are engaged in work with ionising radiation, including radioactive waste management, are given appropriate education, training and information in the field of radiation protection and receive such information and instruction as is suitable and sufficient for them to know: -
    (i) the risks to health created by exposure to ionising radiation;
    (ii) the general principles of radiation protection and the specific radiation protection procedures and precautions in connection with the operational and working conditions of the work with ionising radiation to which they may be assigned;
    (iii) the importance of providing input to risk assessments of the operational and working conditions of the work with ionising radiation to which they may be assigned for the purposes of devising relevant radiation protection procedures;
    (iv) the relevant parts of the emergency response plans and procedures; and
    (v) the importance of complying with the medical, technical and administrative requirements;
b) adequate information is given to other persons who are not directly engaged with the work with ionising radiation carried out by the undertaking or employer to ensure their health and safety so far as is reasonably practicable;
c) all workers, apprentices and students who are engaged in work with ionising radiation are informed of the possible risk arising from ionising radiation to the unborn child and to a nursing infant and of the importance of those workers making an early declaration of pregnancy and the intention to breast feed; and
d) all exposed worker, apprentice and students including outside workers who are engaged in work in a controlled area as classified under Regulation 36 are given specific training in connection with the characteristics of the workplace and the activities within it.

(3) The Provision of education, training and information under this Regulation shall be repeated at appropriate intervals and documented in accordance with guidelines issued by the Agency.

7 SECTION - MAINTENANCE OF RECORDS

All records pertaining to:

- Authorisation of personnel to use sources of ionising radiation;
- Monitoring of personnel using sources of ionising radiation;
- Testing / monitoring of sources of ionising radiation;
- Any aspect of the use of ionising radiation on the University's premises;

are held by the RPO (City Campus) and copies of any relevant documentation must be forwarded to the RPO (City Campus) for collation and inspection by the EPA.

Personal Dosimetry Records

Where deemed necessary a personal dosimeter may be issued to an authorised radiation worker and a list of dosimeter numbers, wearer's names and resulting dosimetry reports will be kept by the RPO. This practice of personal dosimetry is deemed not necessary for staff and students of TU Dublin as Risk Assessment has shown that no exposure of 1mSv per annum will be received.

Monitoring Records

Records of monitoring of areas and persons must be kept for two years and be available when required by Inspectors from the Health and Safety Executive. It is not necessary to keep a record every time a monitor is used to check a dose rate or a contamination level, but it is necessary to keep sufficient records to be able to detect trends taking place or to be able to confirm that Controlled and Supervised Areas are correctly designated and located.

REFERENCES

1. Radiological Protection Act, 1991 (Ionising Radiation) Regulations 2019, S.I. No. 30 of 2019.
2. EPA Licensing Conditions
3. Basic Safety Standards for the Protection of Health Workers and the General Public Against the Dangers of Ionising Radiation, European Council Directive 96/29/EURATOM, Official Journal of the European Communities (1996).
4. A guide to radiation protection in the use of X-ray optics equipment (1986). HHSC ISBN 0 906927 52 4.
5. Dept. of Health and Social Security, 1982. Code of Practice for the Protection of Persons Against Ionising Radiations arising from Medical and Dental Use. 1982.
6. Eichling, John, 1986. Radiation Safety Manual. Washington University and Affiliated Institutions.
7. Kershaw, Belinda, 1994. The Handling and Disposal of Radioactive Materials, The Laboratory Environment. The Royal Society of Chemistry, p125-147.
8. Radiological Protection Institute of Ireland, 1997. Licence for the Custody/Use/Disposal of Radioactive Substances/Nuclear Devices/Irradiating Apparatus.

APPENDICES

APPENDIX A – RADIATION FUNDAMENTALS

1.0 Radiation Fundamentals

For the purposes of this manual, we can use a simplistic model of an atom. The atom can be thought of as a system containing a positively charged nucleus and negatively charged electrons which are in orbit around the nucleus.

The nucleus is the central core of the atom and is composed of two types of particles, protons which are positively charged and neutrons which have a neutral charge. Each of these particles has a mass of approximately one atomic mass unit (amu). (1 amu ≈ 1.66 x 10^{-24} g)

Electrons surround the nucleus in orbitals of various energies. (In simple terms, the farther an electron is from the nucleus, the less energy is required to free it from the atom.) Electrons are very light compared to protons and neutrons. Each electron has a mass of approximately 5.5 x 10^{-4} amu.

A *nuclide* is an atom described by its *atomic number (Z)* and its *mass number (A)*. The Z number is equal to the charge (number of protons) in the nucleus, which is a characteristic of the element. The A number is equal to the total number of protons and neutrons in the nucleus. Nuclides with the same number of protons but with different numbers of neutrons are called *isotopes*.

For example, deuterium ($^{2}_{1}$H) and tritium ($^{3}_{1}$H) are isotopes of hydrogen with mass numbers two and three, respectively. There are on the order of 200 stable nuclides and over 1100 unstable (radioactive) nuclides. Radioactive nuclides can generally be described as those which have an excess or deficiency of neutrons in the nucleus.

1.1 Radioactive Decay

Radioactive nuclides (also called *radionuclides*) can regain stability by nuclear transformation (*radioactive decay*) emitting radiation in the process. The radiation emitted can be particulate or electromagnetic or both. The various types of radiation and examples of decay are shown below.

ALPHA (α)

Alpha particles have a mass and charge equal to those of helium nuclei (2 protons + 2 neutrons). Alpha particles are emitted from the nucleus during the decay of some very heavy nuclides (Z > 83).

$$^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\alpha$$ (where $^{4}_{2}\alpha = {}^{4}_{2}\mathrm{He}^{2+}$)

BETA (β-, β+)

Beta particles are emitted from the nucleus and have a mass equal to that of electrons. Betas can have either a negative charge or a positive charge. Negatively charged betas are equivalent to electrons and are emitted during the decay of neutron rich nuclides.

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\beta + \bar{\nu}_{e}$$

Positively charged betas (positrons) are emitted during the decay of proton rich nuclides.

$$^{22}_{11}\mathrm{Na} \rightarrow {}^{22}_{10}\mathrm{Ne} + {}^{0}_{1}\beta + \gamma$$

GAMMA (γ)

Gammas (also called gamma rays) are electromagnetic radiation (photons). Gammas are emitted during energy level transitions in the nucleus. They may also be emitted during other modes of decay.

$$^{99m}_{43}\mathrm{Tc} \rightarrow {}^{99}_{43}\mathrm{Tc} + \gamma$$

X-RAYS

X-rays are photons emitted during energy level transitions of orbital electrons. *Bremsstrahlung* x-rays (braking radiation) are emitted as energetic electrons (betas) and are decelerated when passing close to a nucleus. Bremsstrahlung must be considered when using large activities of high energy beta emitters such as P-32 and Sr-90.

1.2 Characteristics of Radioactive Decay

In addition to the type of radiation emitted, the decay of a radionuclide can be described by the following characteristics.

The half-life of a radionuclide is the time required for one half of a collection of atoms of that nuclide to decay. Decay is a random process which follows an exponential curve. The number of radioactive nuclei remaining after time (t) is given by:

$$N_t = N_0\, e^{-(0.693t/T)}$$

where N_0 = original number of atoms

N_t = number remaining at time t

t = decay time

T = half-life

The basic unit used to describe the energy of a radiated particle or photon is the electron volt (eV). An electron volt is equal to the amount of energy gained by an electron passing through a potential difference of one volt. The energy of the radiation emitted is a characteristic of the radionuclide. For example, the

energy of the alpha emitted by Cm-238 will always be 6.52 MeV, and the gamma emitted by Ba-135m will always be 268 keV. Many radionuclides have more than one decay route. That is, there may be different possible energies that the radiation may have, but they are discreet possibilities. However, when a beta particle is emitted, the energy is divided between the beta and a neutrino. (A neutrino is a particle with no charge and infinitesimally small mass.)
Consequently, a beta particle may be emitted with an energy varying in a continuous spectrum from zero to a maximum energy (Emax) which is characteristic of the radionuclide.

1.3 Interaction of Radiation with Matter

The transfer of energy from the emitted particle or photon to an absorbing medium has several mechanisms. These mechanisms result in ionisation and excitation of atoms or molecules in the absorber. The transferred energy is eventually dissipated as heat. *Ionisation* is the removal of an orbital electron from an atom or molecule, creating a positively charged ion. In order to cause an ionisation, the radiation must transfer enough energy to the electron to overcome the binding force on the electron. The ejection of an electron from a molecule can cause dissociation of the molecule.
Excitation is the addition of energy to an orbital electron, thereby transferring the atom or molecule from the ground state to an excited state.

1.3.1 Alpha Particles

Interactions between the electric field of an alpha and orbital electrons in the absorber cause ionisation and excitation events. Because of their double charge and low velocity (due to their large mass), alpha particles lose their energy over a relatively short range. One alpha will cause tens of thousands of ionisations per centimeter in air. The range in air of the most energetic alpha particles commonly encountered is about 10 centimeters (4 inches). In denser materials, the range is much less. Alpha particles are easily stopped by a sheet of paper or the protective (dead) layers of skin.

1.3.2 Beta Particles

Normally, a beta particle loses its energy in a large number of ionisation and excitation events. Due to the smaller mass, higher velocity and single charge of the beta particle, the range of a beta is considerably greater than that of an alpha of comparable energy. Since its mass is equal to that of an electron, a large deflection can occur with each interaction, resulting in many path changes in an absorbing medium. If a beta particle passes close to a nucleus, it decreases in velocity due to interaction with the positive charge of the nucleus, emitting x-rays (bremsstrahlung). The energy of the bremsstrahlung x-rays has a continuous spectrum up to a maximum equal to the maximum kinetic energy of the betas. The production of bremsstrahlung increases with the atomic

number of the absorber and the energy of the beta. Therefore, low Z materials are used as beta shields.
A positron will lose its kinetic energy through ionisations and excitations in a similar fashion to a negative beta particle. However, the positron will then combine with an electron. The two particles are annihilated, producing two 511 keV photons called annihilation radiation.

1.3.3 Photons

Gammas and x-rays differ only in their origin. Both are electromagnetic radiation, and differ only from radio waves and visible light in having much shorter wavelengths. They have zero rest mass and travel with the speed of light. They are basically distortions in the electromagnetic field of space, and interact electrically with atoms even though they have no net electrical charge. While alphas and betas have a finite maximum range and can therefore be completely stopped with a sufficient thickness of absorber, photons interact in a probabilistic manner. This means that an individual photon has no definite maximum range. However, the total fraction of photons passing through an absorber decreases exponentially with the thickness of the absorber. There are three mechanisms by which gammas and x-rays lose energy.
The *photoelectric effect* is one in which the photon imparts all its energy to an orbital electron. The photon simply vanishes, and the absorbing atom becomes ionised as an electron (photoelectron) is ejected. This effect has the highest probability with low energy photons (< 50 keV) and high Z absorbers.
Compton scattering provides a means for partial absorption of photon energy by interaction with a "free" (loosely bound) electron. The electron is ejected, and the photon continues on to lose more energy in other interactions. In this mechanism of interaction, the photons in a beam are scattered, so that radiation may appear around corners and in front of shields. *Pair production* occurs only when the photon energy exceeds 1.02 MeV. In pair production the photon simply disappears in the electric field of a nucleus, and in its place two electrons, a negatron and a positron, are produced from the energy of the photon. The positron will eventually encounter a free electron in the absorbing medium. The two particles annihilate each other and their mass is converted into energy. Two photons are produced each of 0.511 MeV. The ultimate fate of these two photons is energy loss by Compton scattering or the photoelectric effect.

1.3.4 Secondary Ionisations

The electrons from ionisations and pair production will themselves go on to cause more ionisation and excitation events in the same way as described for betas.

1.3.5 Radiation Protection

The Concepts of ALARA and Time, Distance and Shielding

Radiation protection of any individual (who is not a hospital patient) is based upon the ALARA principle, which says that the amount of dose to the person must be kept:

As
Low
As is
Reasonably
Achievable

The means by which this is done in practice is to ensure that:

1. The time spent exposed to the source is kept as low as possible. Since radioactive materials decay radioactively with a rate of decay specified by their half-lives, the smaller the time spent in the presence of the source the smaller the number of alpha, beta or gamma particles (exposure) which will be incident on the person, and the smaller the dose that will be received from the source regardless of the type of source. In practice, if it is necessary to be close to the source at any time, do so for as short a time as possible;
2. The distance between the person and the source is kept as high as possible. The number of alpha, beta or gamma particles that hit any point at distance from a radioactive source decreases with the square of the distance from the source (inverse square law) per unit time. Therefore, if one doubles the distance from the source to any point in space, the number of alpha, beta or gamma particles hitting that point will be quartered, and so the dose received will be quartered. As a rule of thumb for low-level sources, if one stands a distance of 2 meters from the source, the dose will be very small. In practice stay as far away from the source as is possible; Shielding is used to limit the number of alpha, beta or gamma particles that exit the source. Materials with high atomic number (e.g. lead) stop alpha, beta or gamma particles easily and reduce the exposure to negligible levels. In practice, 3 mm of lead is usually sufficient to bring the dose from any radioactive emission down to very small levels. In this lab we use 2.5cm lead blocks, which is a very high level of shielding, and reduces the exposure to a very low level;

APPENDIX B - UNSEALED SOURCES

1.0 Procedures for Working with Unsealed Sources

In the case of work with unsealed Sources of Ionising Radiation (which does not take place at present), the authorised staff member in charge must ensure that each student is monitored with a contamination monitor (Berthold LB LB124SC and RadEye B20 multipurpose survey meter) at the end of each laboratory session. He/she must also ensure that the work areas and the room as a whole are clean and uncontaminated at the end of each laboratory session. In the event of a spillage of radioactive material the authorised staff member in charge must be notified immediately and the authorised user must ensure that the work area is immediately decontaminated. The RPO/DRPO must also be informed of the event.

2.0 Monitoring of Laboratory

The designated laboratory as a whole must be thoroughly monitored routinely, where the area is used for experiments with unsealed radioactive material, at least once each week by the laboratory technician or by another member of authorised staff designated by the Radiological Protection Officer. The technician in charge must keep a record of this.

APPENDIX C – DIDACTIC X-RAY SYSTEM SAFETY GUIDELINES

Radiation Safety Guide and Hazard Control Measures for Use of Leybold Didactic X-ray System

Introduction

Basic X-ray devices/apparatus are important tools in experimental undergraduate physics used for teaching purposes. However, the x-rays produced by such devices can pose a hazard to human health. For this reason, special precautions must be observed when these devices are used.

At the Technological University Dublin, any individual who wishes to use the "Didactic X-ray Apparatus (Mo)" within the CQ-123 laboratory, on the Central Quad must first read the radiation protection safety procedure to ensure that he or she is aware of both the potential hazards associated with the use of such devices and the proper precautions that must be employed to minimise these hazards. This document must be read by all new users before commencing their first use of the instrument and signed to verify that they understand these radiation safety procedures. The x-ray tube within this equipment operates between 0 kV - 35 kV with a tube current of 0 mA - 1mA.

1.0 Fundamentals of X-ray Physics

In 1895, the German physicist, Wilhelm Roentgen was studying the fluorescence produced by cathode rays (electrons) when he discovered a form of highly penetrating radiation which he termed "x-rays". Through subsequent experiments, he and other researchers demonstrated that these x-rays possessed the ability to penetrate matter differentially, as a function of density and elemental composition. This led promptly to the widespread application of x-rays for observing the internal structure of various objects, including the human body. Progressive improvements in x-ray technology over the past century have greatly expanded the uses and capabilities of x-ray devices as analytical tools.

1.1 Nature of X-rays

X-rays consist of photons of electromagnetic radiation and are distinguished from gamma rays only by their origin. Whereas gamma rays arise from transitions in the nuclei of radioactive atoms, x-rays are produced from extra nuclear processes involving electrons.

1.2 Production of X-Rays

There are two principal mechanisms by which x-rays are produced. The first mechanism involves the rapid deceleration of a high-speed electron as it enters the electrical field of a nucleus. During this process the electron is deflected and emits a photon of x-radiation. This type of x-ray is often referred to as

bremsstrahlung or **"braking radiation".** For a given source of electrons, a continuous spectrum of bremsstrahlung will be produced up to the maximum energy of the electrons.

The second mechanism by which x-rays are produced is through transitions of electrons between atomic orbits. Such transitions involve the movement of electrons from outer orbits to vacancies within inner orbits. In making such transitions, electrons emit photons of x-radiation with discrete energies given by the differences in energy states at the beginning and the end of the transition. Because such x-rays are distinctive for the particular element and transition, they are called **characteristic x-rays**.

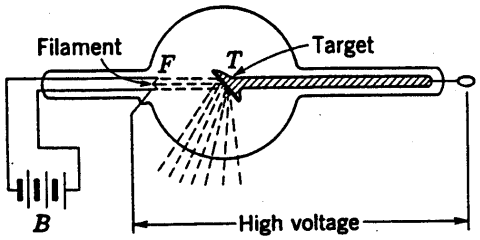


Figure 1. Diagram of a standard x-ray tube

Both of these basic mechanisms are involved in the production of x-rays in an x-ray tube. Figure 1 is a schematic diagram of a standard x-ray tube. A tungsten filament is heated to 2000˚C to emit electrons. These electrons are accelerated in an electric field toward a target, which could be tungsten, copper or molybdenum in this case the target is molybdenum. The interaction of electrons in the target results in the emission of a continuous bremsstrahlung spectrum along with characteristic x-rays from the particular target material. Unlike diagnostic x-ray equipment, which primarily utilise the bremsstrahlung x-rays, the X-ray apparatus makes use of the characteristic x-rays.

1.3 Interaction of X-Rays with Matter

X-rays transfer their energy to matter through chance encounters with bound electrons or atomic nuclei. These chance encounters result in the ejection of energetic electrons from the atom. Each of the electrons liberated goes on to transfer its energy to matter through thousands of direct ionisation events (i.e. events involving collisions between charged particles). Since x-rays and gamma rays transfer energy in this "indirect" manner, they are referred to as "indirectly ionising radiation".

Because the encounters of photons with atoms are by chance, a given x-ray has a finite probability of passing completely through the medium it is traversing. The probability that an x-ray will pass through a medium without interaction depends upon numerous factors including the energy of the x-ray and the medium's composition and thickness.

2.0 Operational Modes of Leybold Didactic X-ray System

The Didactic X-ray Apparatus consists of three basic components: an x-ray source, a specimen support or holder, and a detector, Figure 2.

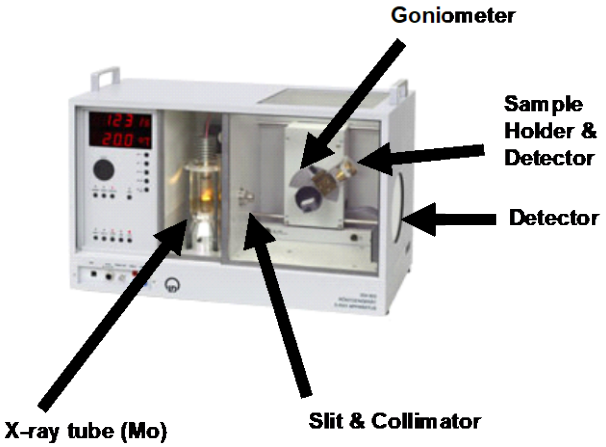


Figure 2. Picture of x-ray apparatus: x-ray tube; slit and collimator assemblies; sample holder & x-ray detector; goniometer scale graduated in degrees.

The Didactic X-ray apparatus can be used for analyzing the structure and properties of solid materials as well as to demonstrate the principles of x-ray and CT imaging. Typical acceleration potentials for devices operating in this mode are from 15 - 35 kVp. This method may be applied in a number of ways depending upon the thickness and form of the sample and the specific results desired. Figure 3 illustrates a typical configuration of a diffraction system. In this example, the primary beam from the target of the x-ray tube emerges from the machine through a collimator and strikes the sample, which diffracts it in a characteristic manner. The diffraction pattern is measured with photographic film or a radiation detector.

The Didactic X-ray apparatus in use within the CQ-123 laboratory, on the TU Dublin Central Quad Grangegorman Campus is termed a “cabinet x-ray system” for protection purposes. This means that the system is completely isolated (shielded) from the user during operation of the instrument, thus preventing any x-ray exposure from occurring to the user. Beam and door interlocks prevent exposure when a sample is being inserted or removed.

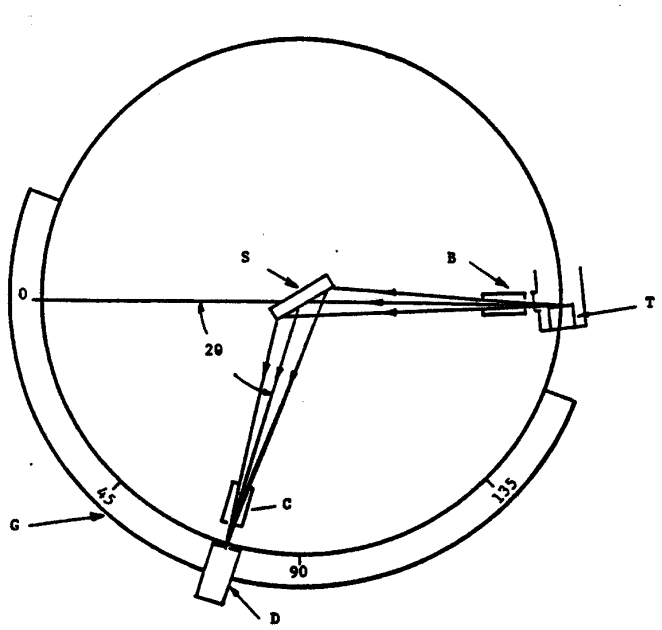


Figure 3. Schematic diagram of x-ray diffractometer:
T, x-ray tube target;
B & C, slit and collimator assemblies;
S, sample holder;
D, x-ray detector;
G, goniometer scale graduated in degrees.

3.0 Enclosed and Open Systems

Many modern X-ray Diffractometers and experimental x-ray apparatus are designed with interlocked barriers that enclose all system components in a manner that prevents radiation levels in excess of 1 micro Sv per hour leaking from the instrument at a distance of 10 cm. Such “enclosed” systems dramatically reduce potential risks to personnel that are inherent in the operation of “open beam” systems.

4.0 Radiation Hazards of the X-ray Diffractometer

The X-ray Diffractometer or experimental apparatus produces highly intense beams of x-rays that are predominantly low in energy relative to those utilised in medical diagnosis and therapy. Such x-rays are often described as being "soft" because of the ease by which they are absorbed in matter. While this characteristic enables soft x-rays to be readily shielded (generally requiring only a few millimeters of lead), it also makes them particularly hazardous since they are highly absorbed even by soft tissue. For example, 10 KeV x-rays will deposit 50 percent of their energy in the first 0.25 millimeters of tissue, which would be classified as dead skin layer.

Potential exposure to the primary x-ray beam, or scattered radiation from the primary x-ray beam is highly unlikely for the Didactic X-ray Apparatus during normal use since it is a closed system (i.e., the x-ray beam is contained within a shielded enclosure). Door interlocks also shut-down the operation of the x-ray tube within the device, if they are opened when the tube is operational, preventing exposure to the operator and individuals in the vicinity of the device. Furthermore, there is an additional safety feature to this device, namely that there is an automatic door locking, which only unlocks the doors, when no x-ray radiation is being generated, as its primary purpose is educational for second and third level students.

5.0 Hazard Control Measures for the Didactic X-ray Apparatus

The requirements for controlling potential exposures associated with equipment are specified in S.I. No. 30 of 2019. Use of the Didactic X-ray Apparatus within the CQ-123 laboratory, on the TU Dublin Central Quad Grangegorman Campus, must comply fully with these regulatory requirements, which are summarised below.

5.1 Equipment Requirements – Exposure Interlocks

The Didactic X-ray Apparatus is fitted with a tube-shutter interlock that may be activated by the user before opening of the front panel (door) of the machine. When the shutter interlock is not closed and the door is opened, the x-ray generator will shut down as a fail-safe precaution. In the Didactic X-ray apparatus there is an automatic door locking, which only unlocks the doors, when no x-ray radiation is being generated. This is tested routinely (at 12 month intervals).

5.2 Area Requirements

5.2.1 Radiation Levels

The x-ray system is sufficiently shielded with lead lining to ensure that radiation leakage from the instrument does not exceed 2 microSv in any one hour.

5.2.2 Surveys

Radiation surveys of all the Didactic X-ray Apparatus sufficient to show compliance with the radiation levels established in 5.2.1 must be performed:

(1) Upon installation of the equipment and at least every twelve months thereafter.
(2) Following any change in the number, type, or arrangement of components in the system.
(3) Following any maintenance requiring the disassembly or removal of a system component.

5.2.3 Posting

The area containing the Didactic X-ray Apparatus shall be conspicuously posted with a sign bearing the radiation symbol and the words "FAINIC – Foinse X-gha in úsáid san áit seo CAUTION – X- Ray Source in Use in this area."

5.3 Operating Requirements

5.3.1 Procedures

Users of the instrument must observe and apply at all times the procedures of use specified in Didactic X-ray Apparatus SOP (refer to Section 2.6.3 of the Radiological Safety Manual).

5.3.2 Bypassing Safety Devices

No individual shall bypass a safety device or interlock unless the individual has obtained written approval from the Radiation Protection Officer.

5.3.3 Altering System Components

No operation involving the removal or alteration of shielding materials, tube housing, shutter, collimators, or beam stops shall be performed until it has been determined that the beam is off and will remain off until conditions have been restored.

6.0 Personnel Monitoring Requirements

The area where the Didactic x-ray Apparatus is being used will be monitored periodically using a calibrated monitor and all individuals will sign the Didactic X-ray Apparatus logbook indicating the date and time at which they started and ended their experiment using the x-ray apparatus.

Users of the device who are aware of, or suspect that they are, pregnant, <u>must</u> notify the RPO / DRPO before commencing use of the device.

7.0 Practical Radiation Protection Measures

The following protection measures should be observed by the users of the instrument throughout their time using the X-ray diffractometer:

7.1 Monitoring

The area where the Didactic X-ray Apparatus is being used is monitored annually by the RPO (City Campus) and RPA using a calibrated monitor which indicates that there is no radiation leakage from the instrument when in operation.

7.2 Door Interlock

During operation of the instrument if the shutter interlock does not operate as expected (i.e. does not activate when pressed before opening the door)

or the door interlock does not operate as expected (i.e. the power does not shut down when the shutter interlock is not activated and the door is opened), immediately shut down the power to the instrument, and leave the room. Inform the RPO (City Campus) and/or DRPO (City Campus) (extensions 5746/5716) of the fault occurrence. Do not attempt to begin using the Didactic X-ray Apparatus again until the RPO (City Campus) and/or DRPO (City Campus) have sanctioned it.

REFERENCES

1. Radiological Protection Act, 1991 (Ionising Radiation) Regulations 2019, S.I. No. 30 of 2019.
2. Radiological Protection Act, 1991 (Ionising Radiation) Order, S.I. No. 125 of 2000.
3. EPA Licensing Conditions, Section E, 2003.
4. Basic Safety Standards for the Protection of Health Workers and the General Public Against the Dangers of Ionising Radiation, European Council Directive 96/29/EURATOM, Official Journal of the European Communities (1996).
5. A guide to radiation protection in the use of X-ray optics equipment (1986). HHSC ISBN 0 906927 52 4.

APPENDIX D – GUIDANCE NOTE FOR WORKING WITH RADIATION WHEN PREGNANT OR BREASTFEEDING

GUIDELINE: Radiation Protection Guidance Note for Working with Radiation when Pregnant or Breastfeeding

File Name: Radiation Protection Guidance Note for Working with Radiation when Pregnant or Breastfeeding	Rev: 2.0	Date of Issue: January 2018
Person Responsible: Radiation Protection Advisory Committee	Document Control: Most recent version available at www.dit.ie/safework	Contact: Jane Torris

PURPOSE

The purpose of this Guidance Note is to explain the risk to expectant and breastfeeding mothers from working with ionising radiation; it applies to any type of radiation, and from any source, whether sealed, unsealed or electrically generated. It also explains what arrangements have been made by the Technological University Dublin to identify the essential precautions that are needed to ensure the protection of the foetus.

SCOPE:

All staff, students, campus users

OBJECTIVES

Identifies the risk to the foetus and outlines the control measures which have been implemented for the protection of the foetus.

GUIDELINE DETAILS

1.1 Risk

The foetus is known to be particularly sensitive to damage by radiation. Therefore it is important that its radiation exposure is kept **as low as reasonably achievable**. Due to the stringent control measures in place at TU Dublin and the type of work done, the estimated annual exposure of staff members is less than 0.2 milliSieverts (mSv, cf. section 5). This is less than both the dose limit of a member of the public and the special dose limit of 1mSv/pregnancy for pregnant women. To ensure that any additional control measures can be activated promptly, it is imperative that the University, usually through the line manager, is informed as soon as possible, when a staff member or contract worker/campus user is pregnant. The specific measures are described in section 1.3 below.

There is no special dose limit for breastfeeding mothers. The only extra risk is where there is the possibility of the uptake and subsequent transfer of radioactive material to a child through the mother's milk. When a mother returns to work, it will be assumed, unless she informs her line manager otherwise, that she is breastfeeding for six months after birth.

1.2 Legal Requirements

Once a pregnancy is confirmed the dose to the foetus must not exceed 1mSv for the rest of the pregnancy. This is regardless of whether the worker is monitored with radiation dosimeters or not. It is however difficult to determine the actual dose to a foetus, therefore the approach of monitoring the exposure of the worker to radiation will ensure that the foetal dose is measured using the radiation dosimeters for the duration of the pregnancy and that it does not exceed 1 mSv. The annual dose to an infant must be limited to not more than 1 mSv per year. In most cases there should be no need to restrict work with radioactive materials as the doses received are unlikely to approach the permitted limit, but occasionally it may be considered prudent for a pregnant worker to curtail a particular aspect of their work e.g. radioiodinations.
It is the employer's (i.e. the University's) responsibility to manage the control of radiation exposure of its employees and other persons. The law is however quite clear that if a pregnant worker does not tell her employer that she is pregnant, the employer is not required to introduce any special measures.

1.3 Controls

The following control measures should be applied when the University' has been informed that a worker is pregnant. To ensure that the risk to the expectant mother or the foetus is minimised, pregnant workers must inform their line manager, in writing, that they are pregnant as soon as possible.
- Once the line manager has been informed, they will then arrange a review of the relevant radiation risk assessment. This should be done in conjunction with the University's Radiation Protection Adviser. As part of the review, any relevant dose records for the pregnant worker will be checked.
- The review of the risk assessment should identify and record any changes or restrictions to work practices that are required to meet the special dose limit. These will be communicated back to the expectant mother within two weeks of the RPAC being informed of the pregnancy. It is important that she co-operates with her line manager in complying with any of these changes or restrictions, and seeks further advice from the Radiation Protection Supervisor for the area or if appropriate from the Radiological Protection Officers of TU Dublin if unsure about anything.

A review of the risk assessment will be undertaken for all relevant workers. However, the following guidelines give some indication of what might be required.

1.4 Exposure to external radiation only

This applies to exposure arising from radiation sources such as sealed sources, undergraduate experimental x-ray systems and analytical x-ray sources. The following guidelines apply to such exposure:

- If the worker is working in an area designated as Supervised due to the external radiation risk, then work may continue and (if not already the case) she should wear a whole-body personal dosimeter (four-weekly wearing period) for the rest of the work with radiation whilst pregnant.
- Currently any work involving sources of ionising radiation within TU Dublin produces a total exposure of less than the 1mSv limit and so no additional controls of restrictions should be necessary for pregnant workers and breastfeeding mothers.

Section 2

2.1 Minimising external radiation exposures.

The fundamental ways of reducing external radiation exposure are:

(i) **Limiting the activity** of the source (or energy of the X-rays) used.
(ii) Placing **shielding** around the source.
(iii) Maintaining **sufficient distance** from the source. Operate the inverse square law concept in which the intensity of the dose is inversely proportional to the square of the distance.
(iv) Reducing the **time of exposure** if (i) to (iii) are not feasible.

This latter option, in particular, necessitates the use of a dose-rate meter and an understanding of the units of dose and dose limitation.

Section 3

3.1 Dose Calculations for year one for Staff and Students within the School of Physics, Clinical and Optometric Sciences in TU Dublin City Campus working with sources of Ionising Radiation

1st Year Physics Laboratories

Staff Dose

The staff would be handling the following sources, 0.0033mSv (8 x Co-60) = 0.0033mSv - for less than 10 minutes for thirty laboratory sessions per year. The estimated maximum achievable dose that they would receive would be 0.0033mSv. This is 1/303th of the annual dose limit of 1mSv per annum for members of the public.

Students

The students will carry out one 2 hour experiment involving a source of ionising radiation, the maximum achievable dose that they would receive would be from Co-60 with a maximum dose of 0.00134mSv, and this is 746 times less than the annual dose limit of 1mSv per annum for members of the public.

2nd Year Physics Laboratories

Staff Dose

The staff would be handling the following sources, 0.0022mSv (Co-60) + 0.156mSv (2X Sr-90) = 0.159mSv, for less than 10 minutes for twenty laboratory sessions per year, the maximum achievable dose that they would receive would be 0.158mSv, and this is 1/6th of the annual dose limit of 1mSv per annum for members of the public.

Students Dose

The students will carry out one 3 hour experiment involving a source of ionising radiation, the maximum dose that they would receive would be from, Co-60 or Sr-90 with a maximum dose of 0.002mSv and 0.141mSv respectively, and this is less than the annual dose limit of 1mSv per annum for members of the public.

3rd Year Physics Laboratories

Staff Dose

The staff would be handling the following sources, 0.000733mSv (Ba-133) + 0.00027mSv (Cd-109) + 0.00027mSv (Co-57) + 0.0027mSv (Co-60) + 0.000137mSv (Cs-137) + 0.00171mSv (Mn-54) + 0.00263mSv (Na-22) + 0.0023mSv (Zn-65) + 0.067mSv (Sr-90(metal)) = 0.07775mSv, for less than 10 minutes for twenty four laboratory sessions per year, the maximum achievable dose that they would receive would be 0.07775mSv, and this is 13 times less than the annual dose limit of 1mSv per annum for members of the public.

Students Dose

The students will carry out one 12 hour experiment involving the following sources of ionising radiation 0.0022mSv (Ba-133) + 0.000137mSv (Cd-109) + 0.000827mSv (Co-57) + 0.00808mSv (Co-60) + 0.000412mSv (Cs-137) + 0.00516mSv (Mn-54) + 0.00792mSv (Na-22) + 0.006936mSv (Zn-65) + 0.1008mSv (Sr-90) the maximum dose that they would receive from this experiment would be 0.1325mSv, and this is 7.5 times less than the annual dose limit of 1mSv per annum for members of the public.

4th Year Physics Laboratories

Staff Dose

The staff would be handling the following sources, 0.000733mSv (Ba-133) + 0.00027mSv (Cd-109) + 0.00027mSv (Co-57) + 0.0027mSv (Co-60) + 0.000137mSv (Cs-137) + 0.00171mSv (Mn-54) + 0.00263mSv (Na-22) + 0.0023mSv (Zn-65) + 0.0669mSv (Sr-90) + 0.03832mSv (C-14)= 0.11597mSv, for less than 10 minutes for twenty four laboratory sessions per year, the maximum achievable dose that they would receive would be 0.11597mSv, and this is 8 times less than the annual dose limit of 1mSv per annum for members of the public.

Students Dose

The students will carry out one 20 hour experiment involving the following sources of ionising radiation 0.00368mSv (Ba-133) + 0.000228mSv (Cd-109) + 0.001378mSv (Co-57) + 0.01347mSv (Co-60) + 0.000686mSv (Cs-137) + 0.0086mSv (Mn-54) + 0.0132mSv (Na-22) + 0.01156mSv (Zn-65) + 0.336mSv (Sr-90) + 0.1924mSv (C-14), the combined maximum dose that they would receive from these experiments would be 0.5812mSv, and this is less than the annual dose limit of 1mSv per annum for members of the public.

Staff

The staff would be in a room containing an X-ray physics system (Max current = 1mA and Max voltage = 35KeV). This X-ray physics system has the following engineering controls, lead shielding, door interlock – when X-rays are being produced the door is locked, if the door is forced open during the experiment the X-ray tube is shut off, both of which ensure that the x-ray leakage from the system is less than 2µSv per hour. Therefore, if a staff member stood beside the system for the 12 hours over thirty laboratory sessions that the system was used their maximum achievable dose would be approximately 0.72mSv, and this is still less than the annual dose limit of 1mSv per annum for members of the public.

Students

The student would be in a room containing an X-ray physics system (Max current = 1mA and Max voltage = 35KeV). This X-ray physics system has the following engineering controls, lead shielding, door interlock – when X-rays are being produced the door is locked, if the door is forced open during the experiment the X-ray tube is shut off, both of which ensure that the x-ray leakage from the system is less than 2µSv per hour. Therefore, if a student stood beside the system for the 12 hours over thirty laboratory sessions that the system was used their maximum achievable dose would be approximately 0.72mSv, and this is still less than the annual dose limit of 1mSv per annum for members of the public.

Research in FOCAS involving X-ray Units – Rigaku XRD and Bruker XRF

Rigaku 600 MiniFlex XRD

The staff would be in a room containing an X-ray physics system with Max current = 15mA and Max voltage = 40KeV. This X-ray physics system has a number of safety features including a RED emergency stop button on the lower front of the instrument, a HV Enable Key to lock off the X-ray generation, a safety switch that cuts power to the top cover if removed, a warning lamp on top of the XRD to show that the X-ray is on, and a door interlock – when X-rays are being produced the door is locked, if the door is forced open during the experiment the X-ray tube is shut off.

Bruker Tracer 5g XRF

The staff would be in a room containing an X-ray physics system with Maximum current = $0.195x10^{-3}$mA and Max voltage = 50KeV. This X-ray physics system has a number of safety features including a radiation warning note which comes on prior to log on, a radiation warning light that must come on when the X-ray is running, a Backscatter check which shuts the X-ray tube off if the count rate falls below a threshold limit and a proximity sensor which checks that an object is within range of the examination window i.e., the X-ray tube will only operate if an object is detected.

These safety features ensure that the x-ray leakage from the XRD and XRF systems is less than 1µSv per hour. The staff who work with the X-ray units monitor them both for leakage radiation on a periodic basis. A radiation survey is carried out on a monthly basis to ensure that the leakage radiation from the XRD and the XRF systems is less than 1µSv per hour. There are currently no practices within the Technological University Dublin that are classified as Supervised due to the external radiation risk.

ROLES AND RESPONSIBILITIES

Staff and campus users to report to line manager when pregnant so that an assessment may be carried out.

Line managers to advise and facilitate

MONITORING, EVALUATION AND REVIEW

Reviewed in line with the EPA licence

DOCUMENTATION

The most recent version of this guidance note will be found on the health and safety website a**t https://www.dit.ie/healthsafety/radiationprotection/**

APPENDIX E – EMERGENCY INTERVENTION PLAN

Radiation Emergency Procedures and Intervention Plan of Technological University Dublin

1. Scope and Current Activities of a Radiological Nature:

As the primary consideration in developing the intervention plan, the activities of a radiological nature within TU Dublin are defined by the EPA [1]. The Technological University Dublin City Campus has in its possession sealed and unsealed radioactive sources and equipment which has the potential to produce X-ray radiation.

1.1 Radioactive Sources

Sealed radioactive sources are used for the purposes of limited undergraduate laboratory practical's and are stored within a lead lined safe in room CQ-123 (Radiation/Medical Physics laboratory; see Appendix E1). The key for the safe in which the sealed sources are stored is secured in a coded safe in the workshop CQ-121 with the access code issued to authorised staff only.

There is a small container of unsealed uranyl acetate powders held in storage - but not currently in use (see Appendix E1), in a lead lined protected floor safe in room CQ-123. Access to the contents of this safe is via a key held in a safe to which the RPO (City Campus)/DRPO (City Campus) have access.

1.2 X-ray Equipment

The licensed x-ray equipment that is in the possession of TU Dublin City Campus are as follows (see Appendix E1):

a) The 'Leybold Didactic X-ray System', which is held within laboratory CQ-123, on the Central Quad Grangegorman Campus, and is used for the purposes of undergraduate laboratories in 3rd and 4th year. The x-ray tube within this equipment operates between 0kV - 35kV with a tube current of 0mA - 1mA.

b) The Rigaku MiniFlex 600 X-ray diffractometer (XRD) which is sited in room B.09.0 of the basement of the FOCAS Research Institute, Camden Row. The maximum tube voltage of this diffractometer is 40 kVp and maximum tube current is 15mA.
c) Research Bruker Tracer 5g Fluorescence unit (XRF) that is sited in room B.18.0 of the basement of the FOCAS Research Institute, Camden Row. It has a range of x-ray generation from 6 – 50kV with 5 - 195µA current and max 4 Watt output.

2. Persons Responsible for the Development and Implementation of This Plan

- The Dean, Faculty of Sciences and Health, TU Dublin (Prof. J.Doran 2205706), who, together with the TU Dublin President, has ultimate responsibility for the development and implementation of the plan;
- The College Manager of the Faculty of Science, TU Dublin (Ms. E. Heffernan, 2205590);
- The Heads of Schools of the Faculty of Science, TU Dublin;
- The TU Dublin Health and Safety Officer (Edel Niland 2206266), and the Safety, Health and Welfare Steering Committee;
- The RPO (City Campus) and Deputy RPO (City Campus) (J. Torris 2205746 and Dr C Flynn 2205716), whose responsibilities in relation to the development of the Plan are detailed in the EPA definition of responsibility of the RPO;
- The Fire Officer at Dublin Headquarters, Townsend Street, Dublin 2 (01 2224000).

3. Objectives and Goals of the Intervention Plan

The main objective of this plan is to [2]:

- *'Prevent the occurrence of deterministic effects in individuals by keeping doses below relevant thresholds and to ensure that all reasonable steps are taken to reduce the occurrence of stochastic effects in the population at present and in the future'.*

The goals of this plan are, in the event of any relevant emergency (as defined in this plan) that may have radiological consequences [1, 2]:

- To identify possible risks within TU Dublin arising out of the scope of its activities with a radiological nature;
- To identify procedures for assessing the seriousness of any relevant emergency as defined in the plan, and to regain control of the situation;

- To prevent the occurrence of deterministic and stochastic health effects in workers and the public arising out of any relevant emergency as defined in the plan;
- To identify procedures for informing the EPA, and emergency services;
- To identify the circumstances in which the emergency services should be involved, the procedures for informing the EPA and emergency services, and the arrangements for medical assistance for dealing with conventional and radiation induced injuries;
- To identify intervention procedures that will minimise the radiation exposure to employees, emergency services and the public that prevent or mitigate consequences at the scene and in the environment of TU Dublin;
- To identify procedures that will be used to investigate the effectiveness of the intervention plan, both on a routine basis and post-accident;
- To identify the mechanisms and personnel involved in the periodic review and update of the intervention plan.

4. Monitoring and Emergency Equipment Associated with the Intervention Plan

The monitoring equipment associated with the plan are the:

- Two Thermo Scientific RadEye B20 monitors (for monitoring of contamination by gamma and beta-emitting substances);
    - One located in CQ-123 of the Central Quad Grangegorman
    - One located in B.09.0 of the FOCAS Research Institute

- Berthold LB124SC (for monitoring of contamination by alpha and beta-emitting substances);
    - Located in CQ-123 of the Central Quad Grangegorman

- One Electronic Personal Dosimeter (EPD), Thermo Electron Corporation Mk 2.3; (in emergency kit held by Porters)

All monitoring equipment (including the EPD) are calibrated annually. Records of Calibration are kept by the RPO (City Campus) and/or DRPO (City Campus).

5. Contact Details of Emergency Services Identified in Plan

Emergency Service	Address	Phone No
Fire Brigade / Ambulance	Townsend Street, Dublin 2	112
Bridewell Garda Station	28/30 Chancery Street, Smithfield, Dublin 7, D07 E424	01 666 8200
First Aid (TU Dublin)	CQ-0372, Central Quad, Grangegorman Lower, Dublin 7	OHO 087-9809135
EPA	PO Box 3000, Johnstown Castle Estate, Wexford, Y35 W821	053 916 0600 /1890 335599
Student Medical Centre (North Side)	Rathdown House, Grangegorman	01 220 7025

6. Risks of Radiological Emergency Associated with the Activities Identified in Section 1

The types of emergency, which have the possibility of occurring within the parameters of the University's activities, are the following:

1. Loss or Theft of Sealed of Unsealed Sources and/or x-ray equipment from the Central Quad Grangegorman.
2. Spillage of material from within the containers of the unsealed sources stored on the Central Quad Grangegorman.
3. Fire resulting in combustion of the sealed or unsealed material stored on the Central Quad Grangegorman or a fire affecting an X-ray machine
4. Damage to Sealed Sources
5. Faults in Safety Systems of Irradiating Apparatus (X-ray equipment)

The following deals with the likelihood of the occurrence of each of the above events, and the risk associated with each of them in the event that they are likely to occur:

1) a) Loss or Theft of Sources:

With regard to the loss or theft of the material that is stored within the safe in room CQ-123 Central Quad Grangegorman, there is an extremely remote possibility that this could occur given that keys to these areas and safes are

kept in safe locations. Quarterly checks on these sources are performed by the RPO (City Campus) and/or the Deputy RPO (City Campus) (as required by the EPA) and records kept by the RPO for inspection by the EPA.

With regard to the theft of the (custody and use) sealed sources that are stored within the safe in room CQ-123, this material is only used for the purposes of undergraduate laboratories.

The staff member or technical officer in charge of a laboratory session in which the material is to be used is responsible for taking the designated number of sealed sources from the safe in Room CQ-123, in their lead transfer container at the start of the laboratory period. He/she must sign the logbook to indicate that the required number of sources have been removed from the safe. At the end of the laboratory session, he/she is responsible for ensuring that the sources are restored back to the safe again using to the lead transfer container and that the log book is signed to indicate that the designated number of sources has been restored to the safe. A log sheet of the sources used by each student is maintained and is signed by the students prior to the laboratory session and after the laboratory session it is completed to indicate that the sources have been returned.

Monthly visual checks on these sources are performed by the RPS (as required by the EPA) and records kept by the RPO (City Campus) for inspection by the EPA. These controls ensure that the material is supervised when in use and the storage arrangements for the material are such that the likelihood of the theft of the material is extremely remote.

b) Theft of X-ray Machines:

With regard to the theft of the X-ray units that are stored within the laboratory CQ-123 on the Central Quad Grangegorman campus, and rooms B.09.0 and B.18.0 in the FOCAS building there is an extremely remote possibility that this could occur given that both buildings have restricted access and all rooms are swipe card controlled.

2) Spillage of Unsealed Material:

With regard to the spillage of the unsealed material that is stored within the safe in room CQ 123, there is an extremely remote possibility that this could occur given that key to this safe is held only by the RPO (City Campus). Quarterly checks on these sources are performed by the RPO (City Campus) and the Deputy RPO (City Campus) and records kept by the RPO. As stated before, this material is not in routine use.

3) Combustion of Material As a Result of Fire:

The total radioactive material held within the storage facilities on the Central Quad Grangegorman Campus is approximately a calibrated figure of 4.185 MBq.

As some of the nuclides in storage are long lived (e.g. Cs^{137} and U^{235}), and pose a radiobiological effect on combustion and/or inhalation [3, 4, 5], the risk of detriment to persons present on the campus during a fire cannot be discounted. The following section will compute the likely risk of combustion and vaporisation of radionuclides in storage on the Central Quad Grangegorman Campus in the event of a fire, and the subsequent risk of detriment to personnel and/or the public as a result of a fire.

Part (i) Section 1; Risk of Combustion of the Material in the Large Floor Safe in Room CQ-123 Central Quad Grangegorman, in the Event of Fire:

The material in storage in Room CQ-123 is stored within a large lead lined floor safe. The detailed construction of this safe is unknown, as records are not in the possession of the RPO (City Campus) with regard to the design of the safe. However, it appears that the safe is constructed from a steel outer casing (1cm thick) with a lead lining of (2cm thick) on the inside of this. The interior lead lining of the safe will melt prior to the outer steel casing in the event of a fire, preventing the combustion of the radioactive material within it. It is therefore considered likely that the safe currently sited on the floor of room CQ-123 will be resistant to fire for a period of time from 30 min to 1 hour after the initiation of a fire. This allows a reasonable response time for the fire services to respond to an emergency at the Central Quad Grangegorman Campus and limit the consequences of a fire, making combustion of this material unlikely.

Part (i) Section 2; Radiological Risk from Combustion of the Material in Room CQ-123, Central Quad, Grangegorman, in the Event of Fire:

The dimensions of Room CQ-123 are approximately 8.15m by 8.79m by 3.6m, giving an overall surface area of approximately 265 m^2, or 2,650,000 cm^2. If the estimated 250 kBq of material was to combust and be deposited equally over the internal surface of the walls of CQ-123, then the resulting contamination on the surface of the walls would be approximately 0.094 kBq/cm^2, which is slightly in excess of the contamination intervention level for public areas specified by the EPA (0.40 Bq/cm^2) [5]. However, for all of this material to ultimately deposit solely on the walls of this room alone is unlikely given the door to this room is constructed from wood. It is more likely that the contamination will be deposited over much of the surface area of the Central Quad Building (surface area approximately 35000 m^2), which would result in a contamination deposited on

the walls of approximately 7.1 mBq/cm^2, which is far below the contamination intervention level for public areas [5].

Estimation of the likely level of committed dose by inhalation/ingestion that would be given to members of the public as a result of combustion of the material stored at this location is difficult to estimate since it depends on many unknowns (combustion properties of nuclides, concentration resulting in the air, prevailing winds etc.) some of which depend on the time at which the event occurs [7].

Estimation of the committed dose to fire fighters as a result of the inhalation of radionuclides that might combust in the fire is also difficult for some of the same reasons, including also the unknown length of time a fire-fighter may need to spend in the vicinity of a fire in order to put it out [6]. However, the risk of inhalation exposure should be eliminated through the usage of personalised breathing apparatus during the fire-fighting stage.

Part (ii) Section 1: Risk of Combustion of the Material in Room CQ-123, Central Quad, Grangegorman, in the Event of Fire:

The material in storage in Room CQ-123, Central Quad, Grangegorman, is stored within a BriTec Shielded Benchtop safe. The outer casing of the safe is a durable epoxy stove enamel finish and the inside is finished with a stainless steel liner. Between the two layers is 50mm of lead. The total dimensions of the safe are 42cm by 42cm by 42 cm. It is estimated by a similar reasoning to that employed in the text above, that with the specification of this safe it will be fire resistant for between 30 mins and 1 hour of the initiation of a fire (melting point of steel 1357˚C; melting point of lead 328˚C). It is likely that in the event of a fire, the lead within the safe will melt prior to the outer casing preventing the combustion of the radioactive material within them. It is therefore considered likely that the safe in room CQ-123 will be resistant to fire for a period of time from 30 mins to 1 hour after the initiation of a fire. This again allows a reasonable response time for the fire services to respond to an emergency at Central Quad, Grangegorman and limit the consequences of a fire, making combustion of this material unlikely.

Part (ii) Section 2; Radiological Risk from Combustion of the Material in Room CQ-123 Central Quad, Grangegorman, in the Event of Fire:

In a similar fashion to the approach adopted in Part (i) above, a calculation of the likely activity deposited on the surface area of room CQ-123 (8.15m by 8.79m by 3.6m) by the combustion of the activity currently in room CQ-123 gives a contamination level on the walls of <1Bq/cm^2, for the activity currently in storage there (3.94 MBq approximately) which is approximately the contamination intervention level for public areas [5].

Estimation of the likely level of committed dose by inhalation/ingestion that would be given to members of the public as a result of combustion of the material stored at this location is difficult to estimate since it depends on many unknowns (combustion properties of nuclides, concentration resulting in the air, prevailing winds etc.) some of which depend on the time at which the event occurs [7].

Estimation of the committed dose to fire fighters as a result of the inhalation of radionuclides that might combust in the fire is also difficult for some of the same reasons, including also the unknown length of time a fire-fighter may need to spend in the vicinity of a fire in order to put it out [6]. However, the risk of inhalation exposure should be eliminated through the usage of personalised breathing apparatus during the fire-fighting stage.

In reality, the fact that all sources are held in a protected safes in rooms and buildings with fire detection and alarm systems should ensure that any fire is detected early and extinguished prior to any sources being affected by the fire. External radiation doses when fighting a fire at normal distance of approx. 3m will not be significant and the use of full face positive pressure breathing apparatus and protective clothing by fire fighters will reduce any risk of internal exposure to ionising radiation.

4) Damage to Sealed Sources:

All sealed sources are subject to routine leak tests at least once every 2 years. If sources fail this leak test, they will not be licensed for use in TU Dublin. However sealed sources may become damaged due to for example, overt mechanical damage, chemical corrosion, or use in hostile conditions. It is important therefore that they are stored and used correctly, and in appropriate conditions. If a sealed source becomes damaged, there is a risk of contamination with the radioactive material contained in the sealed source. Use of the damaged source must discontinue immediately. Sealed radioactive sources at TU Dublin City Campus are stored carefully in safe and segregated storage away from other chemicals, flammables or explosive materials and therefore the risk of damage to sealed sources is minimal.

5) Faults in Safety Systems of Irradiating Apparatus (X-ray equipment):

All irradiating apparatus is routinely and adequately serviced and maintained by a competent person, to ensure that it is in a serviceable condition, and that all safety devices, and interlocks etc. are operational. Irradiating apparatus that is operating incorrectly can be made safe by operating an emergency cut off switch and / or isolating the equipment from the mains supply. It is therefore unlikely that a fault in a safety system will arise that would lead to an overexposure. X-ray equipment on site is designed to be ‘fail safe’ so that the X-ray beam will cut out if a fault in a safety system is detected.

7. Plan of Intervention in the Event of an Emergency as a Result of the Identified Events

Emergency Event 1; Loss or Theft of Source:

Although the possibility of loss or theft of any radioactive source or X-ray equipment is remote, should such an event occur then the following procedures will be implemented:

Stage 1: The RPO (City Campus) and/or DRPO (City Campus) will be informed of the theft of the source in the event that its absence from room CQ-123 is noted by the Laboratory Technician, or in the event that it is found missing from the large floor safe in CQ-123 at Quarterly Check or BriTec Benchtop safe at Monthly Check.

Stage 2: The RPO (City Campus) and/or DRPO (City Campus) will identify the nature and type of source that is missing and will ensure that the source is not present within the boundaries of the laboratories. In searching for the lost or missing source the following matters should be kept in mind:

- Undertake an immediate search for the source if it is thought to be lost.
- While the search is underway, there should be no sweeping of floors, no removal of waste, and no disturbing of furniture etc.
- Examine all relevant records, storage inventories and usage records, speaking to all users, regarding when the material was used last, where it was stored etc.
- If there is any reason to suspect that a lost source might have become damaged, the possibility of contamination by spilled radioactive substance should be borne in mind, and procedure with regard to spillages and decontamination may need to be applied.

Stage 3: If it is confirmed that the source is indeed missing and if theft has been suspected, the RPO (City Campus) or DRPO will contact the local Gardaí (Bridewell Station number 666 8200) and assist them in any subsequent investigations to recover the source. The RPO (City Campus) and/or DRPO (City Campus) will advise the Gardaí on Radiation Protection procedures to be employed in the subsequent location and recovery of the source (as per the Guideline Radiological Accident Management Procedure – see Appendices). The RPO (City Campus) or DRPO (City Campus) will also contact the EPA to inform them of the nature of the emergency and the current stage of the Emergency Response Plan action.

In all such communications with the Gardaí and the EPA the following matters should be kept in mind:

- Give details of the ionising radiation source, its form (sealed, unsealed, irradiating apparatus), and details of the quantity, activity and concentration where relevant.
- Provide as much detail as possible about the circumstances leading to the loss or theft of the item.
- Provide details regarding labelling or packaging of the item, as this will be of relevance if the source is found by or comes into contact with a member of the public. For instance, does it have a radiation trefoil sign, or a Transport Index indicating that it could be hazardous to be in close proximity to the original container?

Stage 4: The RPO (City Campus) or DRPO (City Campus) will inform the College of Sciences and Health Administrator who will inform the TU Dublin Public Relations Officer of the nature of the event and who will, in consultation with the RPO and/or DRPO, take any appropriate action in relation to the contacting and informing of the media regarding the theft of the source (as per the TU Dublin Critical Incident Response Plan – see Appendices);

Stage 5: The RPO (City Campus) and/or DRPO (City Campus) will upon identification of the location of the source by the Gardaí, aid the Gardaí in recovering the source, and will ascertain the likely level of exposure to the individuals involved in the theft and to the Gardaí themselves.

Stage 6: The RPO (City Campus) and/or DRPO (City Campus) will then report to the College of Sciences and Health Director and Administrator, and to the EPA, on the recovery of the source and the concurrent dose estimates, and will contact the emergency services as necessary to discuss prophylactic procedures where such are deemed necessary for any exposed individuals.

Emergency Event 2; Spillage of Un-used Unsealed Material within the safe in CQ123:

The Emergency Response Plan to be adopted in the event that the above event occurs is as follows:

Stage 1: The RPO (City Campus) and/or DRPO (City Campus) will assess the nature and extent of the spillage using the contamination monitors in Room CQ-123, and observing the Guideline Radiological Accident Management Procedure (see Appendices); The RPO will alert people in the vicinity that a spill has occurred and will limit access to the affected area.

Stage 2: The RPO (City Campus) and/or DRPO (City Campus) will put on protective clothing, lab coat, disposable gloves and overshoes and use appropriate cleaning products to remove the spilled material. The RPO will

clean and decontaminate all relevant surfaces, equipment and clothing and will monitor personnel and surfaces with a suitable contamination monitor.

Stage 3: The RPO (City Campus) and/or DRPO (City Campus) will store any contaminated material, associated with the cleaning of the spill, within the large floor safe in room CQ-123 until such time as they have decayed sufficiently to be disposed of in normal waste if relevant or (more likely) will make enquiries to determine how such material can be disposed of as radioactive waste through an authorised waste contractor.

Stage 4: The RPO (City Campus) and/or DRPO (City Campus) will monitor the area of the spill post cleaning to ensure that no residual activity associated with the spill is present;

Stage 5: The RPO (City Campus) and/or DRPO (City Campus) will compile a report on the incident and will provide the report to EPA representatives on inspection.

Emergency Event 3; Fire, Causing Combustion of Sealed and/or Unsealed Material within the safes in Room CQ-123:

The Emergency Response Plan to be adopted in the event that the above event occurs is as follows:

Stage 1: Raise the alarm and evacuate the building. All persons within the Central Quad Building will exit as per the TU Dublin Emergency Information (see https://www.dit.ie/healthsafety/emergencyinformation/#d.en.21709) and according to the Fire Evacuation Route and will observe the Guideline Radiological Accident Management Procedure (see Appendices). You may attempt to fight the fire with an appropriate fire extinguisher, only if you have been trained in the use of fire extinguishers, if the fire is small and manageable, if you have raised the alarm first, and if you have a clear escape route.

You may also consider, if possible, before leaving the lab, removing any sources of ionising radiation within their shielded containers from the immediate danger area. Please note however that your personal safety is of paramount importance in the event of a fire. Do not attempt to fight the fire or remove sources if doing so would endanger your personal safety.

Stage 2: The Emergency Services will be contacted via the Emergency Telephone Number (112).

Stage 3: The emergency services will be supplied with the Emergency Pack (sited in the porters desk, Central Quad) which details the location of the

radioactive material on the campus, and contains a map of the relevant areas of the campus and one EPD.

Stage 4: As stated earlier, the safes in which the material in TU Dublin City Campus, Central Quad Grangegorman is stored are lead lined and will melt and surround their contents when exposed to the heat of a fire above 328°C. However, to ensure that the risk of exposure to airborne radioactive material that could escape the confinement of the safes is minimised, the RPO (City Campus) and/or DRPO (City Campus) will assess the nature and extent of any airborne radioactivity using the contamination monitors in Room CQ-123, once the fire situation has been brought under control. The RPO and/or DRPO will enter the building wearing an EPD (as a means of determining the external exposure level for reporting) and a gas mask (in order to remove exposure to radioactivity through ingestion and/or inhalation – this will need to be supplied by the emergency services);

Stage 5: In the event that airborne contamination is detected in the vicinity of the storage areas, the RPO (City Campus) and/or DRPO (City Campus) will, in conjunction with the emergency services, seal access to these areas. The RPO or DRPO will also contact the EPA to inform them of the nature of the emergency and the current stage of the Emergency Response Plan action, and will inform their representatives of the subsequent progress in implementing the plan;

Stage 6: The RPO (City Campus) or DRPO (City Campus) will inform the College of Sciences and Health Administrator who will inform the TU Dublin Public Relations Officer of the nature of the event and who will, in consultation with the RPO and/or DRPO, take any appropriate action in relation to the contacting and informing of the media regarding the implementation of the Emergency Response Plan (as per the TU Dublin Critical Incident Response Plan – see Appendices);

Stage 7: The RPO (City Campus) and/or DRPO (City Campus) will identify any personnel who may have been exposed to airborne radioactive fumes whilst making the areas safe;

Stage 8: The RPO (City Campus) and/or DRPO(City Campus) will identify the nature and type of radioactivity that might have been combusted in the fire, and from this information, determine the likely consequences resulting from the fire in terms of possible exposures. The RPO will, in consultation with EPA representatives, advise emergency services personnel on appropriate measures to be adopted in aiding the treatment of any exposed personnel;

Stage 9: The RPO (City Campus) and/or DRPO (City Campus) will assess the likely effective dose to the exposed personnel from ingestion and/or inhalation of radioactive fumes using the data compiled in S.I. No. 30 of 2019 [3], and the

measurement of dose received from the electronic personal dosimeters. The RPO and/or DRPO will report to the EPA on the dosimetry assessment results;

Stage 10: The RPO (City Campus) and/or DRPO (City Campus) will conduct a survey of the Central Quad Building, identifying any areas of measurable contamination. If any areas of high contamination are found, the RPO and/or DRPO will restrict access to the building until such time as the contamination is brought to background level. The RPO and/or DRPO will also assess for contamination the filters within the self-contained breathing apparatus used by fire personnel during fighting of the fire, and those used by the RPO and/or DRPO themselves, and will place them in radiological storage if necessary.

Fire affecting an X-ray machine:

Should a fire occur in a room where irradiating apparatus such as X- Ray Machines are used, the machine should be switched off and unplugged, and the general procedures outlined above with regard to raising the alarm, attempting to extinguish the fire, and evacuating the building will also apply thereafter.

If the fire is in the XRD chamber, and the door is open, close the door to limit the access to oxygen. In all cases of fire (inside or outside of the room), turn off the electricity at the mains and turn off the chiller where relevant.

Before reusing any irradiating apparatus after a fire in a room accommodating it (if indeed it is still operational), it should be subject to a full examination by a competent person including testing of safety systems, interlocks etc.

Emergency Event 4: Damage to Sealed Sources

Stage 1: Discontinue use of damaged source immediately. If you suspect that you may have picked up radioactive contamination on your hands do not touch anything until you have been monitored and decontaminated.

Stage 2: Seek advice and assistance from the RPO who will have access to contamination monitors and decontamination materials to deal with such an event.

Stage 3: Potential contamination to personnel involved and equipment will be assessed by the RPO

Stage 4: Procedures with regard to personnel and equipment decontamination will then be applied by the RPO.

Emergency Event 5: Faults in Safety Systems of Irradiating Apparatus (X-Ray Equipment)

Stage 1: Isolate Equipment, Prevent Use and Report to the RPO.

Irradiating apparatus that is operating incorrectly can be made safe by operating an emergency cut off switch and / or isolating the equipment from the mains supply. Any equipment indicating a fault in a safety system such as an interlock must not be used and must be reported at once to the RPO who should instigate the necessary repair / service. The RPO or other authorised person should take charge of the key to the machine (where relevant) to prevent others using the equipment.

Stage 2: Investigate Overexposures.

Any case of overexposure or suspected overexposure must be reported to the RPO for investigation. The RPO will undertake an investigation to determine the likely potential radiation dose and will notify the EPA if necessary. The RPO will liaise with the affected individual with regard to any possible first aid medical attention or follow up action that may be required. The RPO will ensure that measures are implemented to prevent a recurrence of such an overexposure.

8. Testing of Critical Incident Intervention Plan and Protocol for Amendment of Plan

This plan has identified five sets of emergency situations that are deemed possible within the parameters of TU Dublin's current radiological activities.

Testing of the response in relation to these emergency events may involve unnecessary exposures to both staff and the public. However, documented evidence of the response to emergency event 1 by other licensees and institutions, possibly within other jurisdictions, may arise from time to time which may inform TU Dublin with regard to the viability of the current Critical Incident Intervention Plan in respect of this emergency. Therefore:

a. The RPO and/or DRPO will bring any new information which may influence the Critical Incident Intervention Plan to the attention of the TU Dublin Radiation Protection Advisory Committee (RPAC) at its periodic meetings, or at an emergency meeting of same;
b. The RPAC will consider the information presented to it and will decide on appropriate amendments to the plan as it sees fit. Changes will be implemented as per the change control procedure in section 8.

Training on the TU Dublin Radiation Emergency Procedures and Intervention Plan will be undertaken once annually at the annual radiation safety training course. Practical group exercises on emergency scenarios will be undertaken at this training course and will be documented.

9. Change Control Procedure

The Dean of Sciences and Health holds original Copies of this document. Changes to the document must be agreed collectively by the members of the TU Dublin RPAC.

Changes will be reflected in a change of the version number of the document (which will change to *Version (i)-Y*, where *Y* refers to the year in which the change is made). The previous version of the Plan will be revoked after all changes have been made. The RPO (City Campus) holds a copy of all obsolete intervention plans marked 'OBSOLETE' for document retention purposes.

References

1. Guidance Notes on Intervention Planning and Emergency Preparedness for Radiological Accidents, EPA August 2008;
2. Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series, GS-R-2, IAEA, Vienna, 2002;
3. Radiological Protection Act, 1991 (Ionising Radiation) Regulations 2019, S.I. No. 30 of 2019.
4. EPA Licensing Conditions
5. Basic Safety Standards for the Protection of Health Workers and the General Public Against the Dangers of Ionizing Radiation, European Council Directive 96/29/EURATOM, Official Journal of the European Communities (1996).
6. ICRP Publication 68, Dose Coefficients for Intakes of Radionuclides by Workers, ICRP Annals (1994).

Appendix E1 – List of Sealed and Unsealed Material at TU Dublin City Campus

Source	Activity	Label
Am^{241}	1850 kBq	Metal (Rutherford Scattering apparatus)
Sr^{90} – 1	333 kBq	S4
Sr^{90} – 2	185 kBq	SR90 (metal)
Co^{60} – 1	37 kBq	October 2011(Spectrum Techniques)
Co^{60} – 2	37 kBq	October 2011(Spectrum Techniques)
Co^{60} – 3	37 kBq	October 2011(Spectrum Techniques)
Co^{60} – 4	37 kBq	October 2011(Spectrum Techniques)
Co^{60} – 5	37 kBq	October 2011(Spectrum Techniques)
Co^{60} – 6	37 kBq	October 2011(Spectrum Techniques)
Co^{60} – 7	37 kBq	October 2011(Spectrum Techniques)
Co^{60} – 8	37 kBq	October 2011(Spectrum Techniques)
Cs^{137} – 1	37 kBq	September 2011 (Spectrum Techniques)
Cs^{137} – 2	37 kBq	September 2011 (Spectrum Techniques)
Cs^{137} – 3	370 kBq	CS2
Co^{60} – 9	185 kBq	Metal
Co^{60} – T1	37 kBq	October 2011(Spectrum Techniques)
Co^{57} – T2	37 kBq	September 2018 (Spectrum Techniques)
Cs^{137} – T3	3.7 kBq	October 2011(Spectrum Techniques)
Mn^{54} – T4	37 kBq	September 2018 (Spectrum Techniques)
Na^{22} – T5	37 kBq	September 2018 (Spectrum Techniques)
Cd^{109} – T6	37 kBq	September 2018 (Spectrum Techniques)
Ba^{133} – T7	37 kBq	October 2011(Spectrum Techniques)
Zn^{65} – T8	37 kBq	September 2018 (Spectrum Techniques)
C^{14}	370 kBq	September 2013 (Spectrum Techniques)
Am^{241}	9.5 kBq	Metal
U^{235} (25g)	10kBq/g	Unsealed Source (Agar Scientific)

X- Ray Units

Location	Tube Voltage	Description
CQ-123	0 – 35kV	Leybold Didactic Closed X-Ray System
B.09.0	Max 40kV	Rigaku Miniflex 600 X-Ray Diffractometer
B.18.0	6 – 50kV	Bruker tracer 5g X-Ray Fluorescence

Appendix E2 – Fire Evacuation Procedure for TU Dublin City Campus, Central Quad, Grangegorman

EVACUATION AND DRILL PROCEDURES

If you discover a fire/emergency situation

- Activate the nearest fire alarm call point
- Alert the front desk/porters if possible
- Follow the evacuation procedure below**.**

If you hear the evacuation alarm

- Proceed to evacuate without delay, do not wait for further information or instruction
- If there is time and it is safe to do so, shut down electricity and gas, and close doors and windows
- Leave the building using the nearest emergency exit
- Do not use the lift
- Form a single file on stairways and corridors and leave the centre passageway clear for emergency access
- If you encounter crowd congestion, smoke or other danger proceed to another exit if possible
- Disperse from the building and report to the designated assembly point

  Assembly Point – Playing Pitch
- Do not re-enter the building until the “all clear” has been given by the Incident Officer
- Return to the building in an orderly and safe manner.

Appendix E3 – TU Dublin Critical Incident Response Plan

1. **PURPOSE**

The purpose of this plan is to set out procedures which will be followed in order to ensure a timely and co-ordinated response by TU Dublin to critical incidents and urgent situations involving staff, students, contractors and visitors to TU Dublin.

The plan is intended to be set in motion whenever a natural or man-made crisis effecting the University reaches proportions that cannot be handled by means of normal procedures. The plan is intended to be sufficiently flexible to accommodate contingencies of all types, magnitudes and duration. It should be read in conjunction with the corporate manual for management of fire and other emergency situations.

2. **DEFINITION OF CRITICAL INCIDENT**

A critical incident is defined as one that:

i) causes or threatens death or serious injury to a member of staff or student of the University.

or

ii) causes serious physical or environmental damage to the buildings of the University or their surroundings.

or

iii) causes significant disruption of the business of the University

or

iv) poses a serious threat to the University's public image.

Examples of critical incidents would include inter alia a serious fire; a leak or spillage of hazardous material; a terrorist incident or criminal activity; a flood or other disaster.

3. **FOUR STAGES OF CRITICAL INCIDENT MANAGEMENT**

The University's response to a critical incident will consist of the following four stages:

i) Immediate response/intervention
ii) Secondary response/referral to external agencies
iii) Post incident response/debriefing and counselling (where necessary)
iv) Review/ was the incident handled appropriately?

4. AUTHORITY TO DECLARE A CRITICAL INCIDENT

The University will nominate the Chair of each Campus Safety Team or in his/her absence a nominee who will have authority to declare a state of emergency and initiate the critical incident plan.

5. CRITICAL INCIDENT MANAGEMENT TEAMS

The Campus Safety Team will nominate a team in each building to deal with critical incidents. One person from this team will be the nominated decision-maker who will be solely responsible for making specific decisions in relation to the management of critical incidents.

Local Teams of six people to be made up as follows:

i) Director and College Manager
ii) Employee Assistance Programme (EAP)/Local Counsellor
iii) Buildings Maintenance Manager
iv) Medical Staff i.e. Nurse or Staff member with First Aid Training
v) Members of Emergency Response Team (ERT)
vi) Chaplain.

The group will nominate a person to liaise with Public Relations (PR) and Site President/Student Reps.

6. CRITICAL INCIDENT MANAGEMENT PRIORITIES

In managing critical incidents affecting the University, critical incident management teams will have regard to the following criteria:

i) Protect Human Life/Minimise Personal Injury
ii) Minimise negative psychological impact
iii) Protect the Environment
iv) Minimise damage to physical assets
v) Restore normal operations

7. PROCEDURES AND RESPONSIBILITIES

The procedures and responsibilities in relation to particular critical incidents will vary according to the nature of the critical incident.
In relation to potentially hazardous incidents for which emergency plans already exist, the emergency plan will be initiated immediately, and will form part of the Critical Incident Response, if appropriate. The decision maker of the local Critical Incident Team will decide whether or not a critical incident exists in any particular circumstances, and if so, what measures need to be taken in addition to the implementation of the Emergency Plan.

In relation to incidents for which Emergency Plans do not exist, the decision maker of the local Critical Incident Team will decide whether a critical incident exists in the circumstances applying, and if so, what measures need to be taken.

8. **COMMUNICATIONS**

All communications will be the responsibility of the Public Affairs Office.

9. **DISABLED STAFF AND STUDENTS**

Critical incident management teams will have regard to a protocol in relation to the special needs of staff and students with various forms of disability during the management of different types of critical incident.

10. **REFERENCE DOCUMENTS**

Faculty/Function safety statements
Spill procedures
Procedure for bomb threats
Corporate manual for management of fire and other emergency situations

Appendix E4 – Guideline Radiological Accident Management Procedure

At all times observe the 'Time-Distance-Shielding' Maxim:

- Limit your time near the source of radioactivity/radiation to a minimum;
- Maintain your distance from the source of radioactivity/radiation to the maximum possible;
- If possible, use any available shielding to limit your exposure to source of radioactivity/radiation to a minimum;

This will ensure any doses from radioactive materials/radiation is maintained to as low a level as possible. When responding to an radiological emergency

1. Contact the RPO (City Campus)/DRPO (City Campus) as soon as possible (J. Torris ext. 5746 and Dr C. Flynn ext. 5716);

2. Do not panic;

3. Never touch a radioactive source. Maintain your distance from the source of radioactivity/radiation to as large an extent as possible;

4. Prevent unauthorised access to the site of the incident

APPENDIX F – RISK ASSESSMENTS AND RADIONUCLIDE SAFETY DATA SHEETS

Risk Assessment for Work with Ionising Radiation

Regulation 31 of the Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019 (SI 30 of 2019) requires that Technological University Dublin (TU Dublin), makes an assessment of the nature and magnitude of the risks of exposure to ionising radiation arising from any practice for workers and members of the public who may be affected.

Furthermore, Categorisation of Exposed Workers is required under Regulation 39 of the Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019 – SI 30 of 2019.

An 'Exposed Worker' is defined in SI No. 30 of 2019 as a person who is subject to exposure at work carried out within a work practice regulated by these Regulations and who is liable to receive doses exceeding one or other of the dose limits for public exposure, i.e. an effective dose that exceeds 1mSv per year (Regulation 27 – SI 30 of 2019).

Exposed workers can be further categorised as 'Category A' or 'Category B' workers. 'Category A' workers are liable to receive an effective dose of greater than 6mSv in a year. 'Category B' workers are exposed workers who are liable to receive an effective dose of greater than 1mSv but less than 6mSv in a year.

Regulation 39 (2) of SI 30 of 2019 requires that the categorisation shall take into account potential exposures including, where relevant, the results of any individual radiological monitoring.

The purpose of this document is to undertake a risk assessment on all sources of ionising radiation at Technological University Dublin, to determine the nature and magnitude of the risk, and to also use the results of this risk assessment to categorise the workers appropriately in accordance with the requirements of SI 30 of 2019.

Risk Quantification

Risk is assessed by looking at both the likelihood of a radiation exposure occurring and the possible consequences of such an exposure (severity). The tables below are used as a guide to quantify the risk.

1. LIKELIHOOD SCORING

Rare/Remote (1)		Unlikely (2)		Possible (3)		Likely (4)		Almost Certain (5)	
Actual Frequency	Probability	Actual Frequency	Probability	Actual Frequency	Probability	Actual Frequency	Probability	Actual Frequency	Probability
Occurs every 5 years or more	1%	Occurs every 2-5 years	10%	Occurs every 1-2 years	50%	Bimonthly	75%	At least monthly	99%

2. SEVERITY SCORING – BASED ON LIKELY RADIATION DOSE

Insignificant Dose	Dose >1 mSv per year	Dose >6 mSv per year	Dose > 20 mSv per year	Dose >100 mSv per year
1	2	3	4	5

3. RISK MATRIX

	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Almost Certain (5)	5	10	15	20	25
Likely (4)	4	8	12	16	20
Possible (3)	3	6	9	12	15
Unlikely (2)	2	4	6	8	10
Rare/Remote (1)	1	2	3	4	5

School of Physics, Clinical and Optometric Sciences TU Dublin City Campus, Central Quad – 1st Floor East Undergraduate Teaching Laboratories

Activity	**Hazard - Exposure to Ionising Radiation**	**Likelihood (L) x Severity (S)** **No Controls**	**Risk Potential Dose** No Controls Exceptional Circumstances Accident/Incident	**Controls**	**Likelihood (L) x Severity (S)** **Controls in Place**	**Risk Expected Dose** Planned Exposure All Control Measures in Place
Work with Sealed Sources	Potential external exposure to ionising radiation from work with sealed teaching sources (dose calculation does not exceed 1mSv/yr for any source). Potential contamination or internal radiation exposure from leaking source.	**L = 2** **S = 1**	**2 (Low)**	• Sources are shielded. • Tongs used to transfer sources. • Calibrated contamination monitor available. • Training. • Secure storage • Supervision during practicals. • Restricted Access • Warning Signage in place • Spill Kit	**L=1** **S=1**	**1 (Low)**

Theft / Loss of Source	Possible overexposure to ionising radiation	**L = 2** **S = 1**	**2 (Low)**	• All sources signed out in log book to undergraduate laboratory and logged back in again at end of session. • Sources returned by the laboratory supervisor to room CQ123, before the end of the practical and before students leave the teaching laboratory. • CCTV in building • Access control policy and swipe card access. • Rooms locked when not in use. • Radiological warning signage on exterior of room door. • Supervision during practicals • Monthly stock check of sources by DRPS • Building alarmed at night. • Security staff on premises 24 hours a day throughout the year.	**L = 1** **S = 2**	**2 (Low)**

				• Security Alarm Installed • Laboratory CQ123 locked except when laboratory in use. • Secure storage		
Faulty Source / Damage to Source	Leaking of source or damaged shielding leading to exposure to ionising radiation.	**L = 2** **S = 2**	**4 (Low)**	• Students supervised by trained and approved staff • Operation restricted to trained, approved staff • Warning signage in place • Routine checks by DRPS • Fire authorities have been notified of location • All sealed sources to be wipe tested biannually. • Monthly inventory	**L = 1** **S = 2**	**2 (Low)**
Fire Affecting Source	Damage to source and shielding leading to exposure to ionising radiation	**L = 2** **S = 2**	**4 (Low)**	• There are no flammable materials, or other hazardous materials such as explosives, oxidising agents or corrosive materials stored or used near to the sources. • There is a smoke detection and alarm system in the rooms and	**L = 1** **S = 2**	**2 (Low)**

				buildings containing the sources • Fire extinguishers in place • Good security on site reduces the risk of arson. • Fire Officer is notified of radioactive sources on site. • All staff act as wardens in the event of a fire on site		

Risk Quantification – Potential Doses without Operational Controls (Exceptional Circumstances)

Hazard: Exposure to Ionising Radiation

Persons at Risk:

- Staff
- Students
- Public
- Contractors
- Emergency personnel

Risk: Low, Based on 3x2 risk matrix above

Likelihood: 2

Severity: 1

Overall Risk: 2

Result: Low Risk

Explanation: With no operational controls in place it is unlikely that an individual would exceed a radiation dose of 1mSv which is the legal allowable limit or members of the public. Sources are all low activity (kBq level).

Risk Quantification – Planned Exposures - Expected Doses with Operational Controls

Hazard: Exposure to Ionising Radiation

Persons at Risk:

- Staff
- Students
- Public
- Contractors
- Emergency personnel

Risk: Low, Based on 1x2 risk matrix above

Likelihood: 1

Severity: 2

Overall Risk: 2

Result: Low Risk

Explanation: With all operational controls in place it would be rare (occurs less than every 5 years) that any individual may receive a radiation dose of any significance. Individuals are unlikely to exceed the annual dose limit for a member of the public of 1 mSv.

Classification of Workers Based on Results of this Risk Assessment

Taking the dose estimates and quantified risk assessments into account it is considered unlikely that an employee would exceed the annual radiation dose limit for a member of the public of 1 mSv. Workers in this area do not need to be categorised as 'Exposed Workers' and personal dosimetry monitoring is not required.

Note: This risk assessment and the categorisation of workers should be kept under review and may be subject to change based on factors such as future dosimetry results, changes in the nature or type of work or sources of ionising radiation and ongoing training of current and new employees.

Categorisation of Work Areas Based on Results of this Risk Assessment

The work areas do not need to be categorised as 'Controlled' or 'Supervised' Areas but should be signposted with the ionising radiation hazard warning symbol.

RADIONUCLIDE SAFETY DATA SHEETS

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 1st Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Co-60
Form: Solid Sealed Source</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 1.3325 MeV and 0.3178 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 5.271 years</td><td>Frequency of Experiment / per year
30 times per year</td></tr>
<tr><td colspan="2">Co-60 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Co-60 Source
Original Activity of Co-60 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.67 µSv/hr
Dose Rate of 0.0067 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 30 times per year (dose limit applies to annual dose)

Co-60 0.166 x 30 x 0.67 = 3.3 µSv
Total Dose < 0.004 mSv per year

Dose laboratory student will receive per experiment
2 hours handling source once per year (dose limit applies to annual dose)
Co-60 2 x 1 x 0.67 = 1.34 µSv
Total Dose < 0.002 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 1st Year Students < 0.004mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 2nd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Co-60
Form: Solid Sealed Source</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 1.3325 MeV and 0.3178 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 5.271 years</td><td>Frequency of Experiment / per year
20 times per year</td></tr>
<tr><td colspan="2">1 Co-60 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Co-60 Source
Original Activity of Co-60 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm =0.67 µSv/hr
Dose Rate of 0.0067 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 20 times per year (dose limit applies to annual dose)

Co-60 0.166 x 20 x 0.67 = 2.22 µSv = 0.0022 mSv
Total Dose < 0.0022 mSv per year

Dose laboratory student will receive per experiment
3 hours handling source once per year (dose limit applies to annual dose)

Co-60 3 x 1 x 0.67 = 2.01 µSv
Total Dose < 0.002 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 2nd Year Students < 0.002mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

Radionuclide Safety Data Sheet for 2nd Year Experiments involving Ionising Radiation

Nuclide: Sr-90
Form: Solid Sealed Source

Physical Characteristics

Primary Radiation: Beta	**Energy of Principle emissions** : 546 keV
Physical Half-Life [T½]: 28.2 years	**Frequency of Experiment / per year** 20 times per year

2 Sr-90 sources in use in the School of Physics, Clinical and Optometric Sciences: (1) SR^{90}-1 (S4)**;**
(2) SR^{90}-2 (Metal)

Details of Dose Rate for Sr-90 Sources

(1) SR^{90}-1 (S4)
Original Activity of S4 = 0.333MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 30.3 µSv/hr
Dose Rate of 0.303 µSv/hr @ 1 m (without shielding)

(2) SR^{90}-2 (Metal)
Original Activity of Sr-90 Metal = 0.185MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 16.8 µSv/hr
Dose Rate of 0.168 µSv/hr @ 1 m (without shielding)

External Exposure
Dose laboratory technician will receive per year
10 mins handling source 20 times per year (dose limit applies to annual dose)

(1) SR^{90}-1 (S4) 0.166 x 20 x 30.3 = 100.6 µSv = **0.101 mSv**
(2) SR^{90}-2 (Metal) 0.166 x 20 x 16.8 = 55.8 µSv = **0.0558 mSv**
Total Dose < 0.156 mSv per year

Dose laboratory student will receive per experiment
3 hours handling source once per year (dose limit applies to annual dose)
(1) SR^{90}-1 (S4) 3 x 1 x 30.3 = 90.9 µSv = **0.091 mSv**
(2) SR^{90}-2 (Metal) 3 x 1 x 16.8 = 50.4 µSv = **0.0504 mSv**
Total Dose < 0.141 mSv per year

Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 2nd Year Students < 0.16mSv/year)

Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.

Radionuclide Safety Data Sheet for 2nd Year Experiments involving Ionising Radiation

Nuclide: Cs-137
Form: Solid Sealed Source

Physical Characteristics

Primary Radiation: Gamma and Beta	**Energy of Principle emissions** : 0.662 MeV and 0.512 MeV
Physical Half-Life [T½]: 30.17 years	**Frequency of Experiment / per year** 24 times per year

2 x Cs-137 (37kBq) sources in use in the School of Physics, Clinical and Optometric Sciences (EHOs)
1 x Cs-137 (370kBq) source in use in the School of Physics, Clinical and Optometric Sciences (EHOs)

Details of Dose Rate for Cs-137 Sources

Cs-137 (37kBq)
Original Activity of Cs-137 = 0.037MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.343 µSv/hr
Dose Rate of 0.00343 µSv/hr @ 1 m (without shielding)

Cs-137 (370kBq)
Original Activity of Cs-137 Metal = 0.37MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 3.43 µSv/hr
Dose Rate of 0.0343 µSv/hr @ 1 m (without shielding)

External Exposure
Dose laboratory technician will receive per year
10 mins handling source 12 times per year (dose limit applies to annual dose)

Cs-137 (37kBq) 0.166 x 12 x 0.343 = 0.683 µSv = **0.000683 mSv**
Cs-137 (370kBq) 0.166 x 12 x 3.43 = 6.83 µSv = **0.00683 mSv**
Total Dose < 0.0075 mSv per year

Dose laboratory student will receive per experiment
2 hours using source twice per year (dose limit applies to annual dose)
Cs-137 (37kBq) 2 x 2 x 0.343 = 1.372 µSv = **0.00137 mSv**
Cs-137 (370kBq) 2 x 2 x 3.43 = 13.72 µSv = **0.0137 mSv**
Total Dose < 0.0151 mSv per year

Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 2nd Year Students < 0.02mSv/year)

Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Co-60
Form: Solid Sealed Source (T1)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 1.3325 MeV and 0.3178 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 5.271 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Co-60 source in use in the School of Physic, Clinical and Optometric Sciences

Details of Dose Rate for Co-60 Source
Original Activity of Co-60 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.6734 µSv/hr
Dose Rate of 0.00673 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Co-60 0.166 x 24 x 0.6734 = 2.68 µSv = 0.0027 mSv
Total Dose < 0.003 mSv per year

Dose laboratory student will receive per experiment
6 hours handling source twice per year (dose limit applies to annual dose)

Co-60 6 x 2 x 0.6734 = 8.08 µSv
Total Dose < 0.008 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3rd Year Students < 0.008mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Co-57
Form: Solid Sealed Source (T2)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 0.122 MeV and 0.136MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 271 days</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Co-57 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Co-57 Source
Original Activity of Co-57 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.0689 µSv/hr
Dose Rate of 0.000689 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Co-57 0.166 x 24 x 0.0689 = 0.27 µSv
Total Dose < 0.001 mSv per year

Dose laboratory student will receive per experiment
6 hours handling source twice per year (dose limit applies to annual dose)

Co-57 6 x 2 x 0.0689 = 0.827 µSv
Total Dose < 0.001 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3rd Year Students < 0.001mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Cs-137
Form: Solid Sealed Source (T3)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 0.662 MeV and 0.512 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 30.17 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Cs-137 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Cs-137 Source
Original Activity of Cs-137 = 0.0037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.0343 µSv/hr
Dose Rate of 0.000343 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Cs-137 0.166 x 24 x 0.0343 = 0.137 µSv
Total Dose < 0.0002 mSv per year

Dose laboratory student will receive per experiment
6 hours handling source twice per year (dose limit applies to annual dose)
Cs-137 6 x 2 x 0.0343 = 0.412 µSv
Total Dose < 0.0005 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3rd Year Students < 0.0005mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Mn-54
Form: Solid Sealed Source (T4)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma</td><td>Energy of Principle emissions : 0.835MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 313 days</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Mn-54 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Mn-54 Source
Original Activity of Mn-54 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.43 µSv/hr
Dose Rate of 0.0043 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Mn-54 0.166 x 24 x 0.43 = 1.71 µSv
Total Dose < 0.002 mSv per year

Dose laboratory student will receive per experiment
6 hours handling source twice per year (dose limit applies to annual dose)

Mn-54 6 x 2 x 0.43 = 5.16 µSv
Total Dose < 0.006 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3rd Year Students < 0.006mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Na-22
Form: Solid Sealed Source (T5)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and positron emission</td><td>Energy of Principle emissions : 1.275 MeV and 0.545 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 2.6 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Na-22 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Na-22 Source
Original Activity of Na-22 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.66 µSv/hr
Dose Rate of 0.0066 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Na-22 0.166 x 24 x 0.66 = 2.63 µSv
Total Dose < 0.003 mSv per year

Dose laboratory student will receive per experiment
6 hours handling source twice per year (dose limit applies to annual dose)

Na-22 6 x 2 x 0.66 = 7.92 µSv
Total Dose < 0.01 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3rd Year Students < 0.01mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Cd-109
Form: Solid Sealed Source (T6)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma</td><td>Energy of Principle emissions : 0.022 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 464 days</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Cd-109 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Cd-109 Source
Original Activity of Cd-109 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.0114 µSv/hr
Dose Rate of 0.000114 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Cd-109 0.166 x 24 x 0.0114 = 0.27 µSv
Total Dose < 0.001 mSv per year

Dose laboratory student will receive per experiment
6 hours handling source twice per year (dose limit applies to annual dose)

Cd-109 6 x 2 x 0.0114 = 0.137 µSv
Total Dose < 0.001 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3rd Year Students < 0.001mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Ba-133
Form: Solid Sealed Source (T7)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 0.356 MeV and 0.32 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 10.74 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Ba-133 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Ba-133 Source
Original Activity of Ba-133 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.184 µSv/hr
Dose Rate of 0.00184 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Ba-133 0.166 x 24 x 0.184 = 0.733 µSv
Total Dose < 0.001 mSv per year

Dose laboratory student will receive per experiment
6 hours handling source twice per year (dose limit applies to annual dose)

Ba-133 6 x 2 x 0.184 = 2.2 µSv
Total Dose < 0.003 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3rd Year Students < 0.003mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Zn-65
Form: Solid Sealed Source (T8)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma</td><td>Energy of Principle emissions : 1.115 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 245 days</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Zn-65 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Zn-65 Source
Original Activity of Zn-65 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.578 µSv/hr
Dose Rate of 0.00578 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Zn-65 0.166 x 24 x 0.578 = 2.30 µSv
Total Dose < 0.003 mSv per year

Dose laboratory student will receive per experiment
6 hours handling source twice per year (dose limit applies to annual dose)

Zn-65 6 x 2 x 0.578 = 6.936 µSv
Total Dose < 0.007 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3rd Year Students < 0.007mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

Radionuclide Safety Data Sheet for 3rd Year Experiments involving Ionising Radiation	
Nuclide: Sr-90 **Form:** Solid Sealed Source	
Physical Characteristics	
Primary Radiation: Beta	**Energy of Principle emissions** : 546 keV
Physical Half-Life [T½]: 28.2 years	**Frequency of Experiment / per year** 24 times per year
2 Sr-90 sources in use in the School of Physics, Clinical and Optometric Sciences: **(1) SR^{90}-1** (S4)**;** **(2) SR^{90}-2** (Metal) **Details of Dose Rate for Sr-90 Sources** **(1) SR^{90}-1** (S4) Original Activity of S4 = 0.333MBq Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 30.3 µSv/hr Dose Rate of 0.303 µSv/hr @ 1 m (without shielding) **(2) SR^{90}-2** (Metal) Original Activity of Sr-90 Metal = 0.185MBq Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 16.8 µSv/hr Dose Rate of 0.168 µSv/hr @ 1 m (without shielding)	
External Exposure **Dose laboratory technician will receive per year** **10 mins handling source 24 times per year (dose limit applies to annual dose)** (1) SR^{90}-1 (S4) 0.166 x 24 x 30.3 = 120.7 µSv = **0.1207 mSv** (2) SR^{90}-2 (Metal) 0.166 x 24 x 16.8 = 66.9 µSv = **0.0669 mSv** **Total Dose < 0.188 mSv per year** **Dose laboratory student will receive per experiment** **6 hours handling source once per year (dose limit applies to annual dose)** (1) SR^{90}-1 (S4) 6 x 1 x 30.3 = 181.8 µSv = **0.1818 mSv** (2) SR^{90}-2 (Metal) 6 x 1 x 16.8 = 100.8 µSv = **0.1008 mSv** **Total Dose < 0.283 mSv per year**	
Dose Constraint Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 3nd Year Students < 0.3mSv/year)	
Special Precautions Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.	

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Co-60
Form: Solid Sealed Source (T1)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 1.3325 MeV and 0.3178 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 5.271 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Co-60 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Co-60 Source
Original Activity of Co-60 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.6734 µSv/hr
Dose Rate of 0.00673 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Co-60 0.166 x 24 x 0.6734 = 2.68 µSv = 0.0027 mSv
Total Dose < 0.003 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)

Co-60 9 x 2 x 0.6734 = 12.12 µSv
Total Dose < 0.013 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.013mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Co-57
Form: Solid Sealed Source (T2)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 0.122 MeV and 0.136MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 271 days</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Co-57 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Co-57 Source
Original Activity of Co-57 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.0689 µSv/hr
Dose Rate of 0.000689 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Co-57 0.166 x 24 x 0.0689 = 0.27 µSv
Total Dose < 0.001 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)

Co-57 9 x 2 x 0.0689 = 1.24 µSv
Total Dose < 0.002 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.002mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Cs-137
Form: Solid Sealed Source (T3)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 0.662 MeV and 0.512 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 30.17 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Cs-137 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Cs-137 Source
Original Activity of Cs-137 = 0.0037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.0343 µSv/hr
Dose Rate of 0.000343 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Cs-137 0.166 x 24 x 0.0343 = 0.137 µSv
Total Dose < 0.0002 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)
Cs-137 9 x 2 x 0.0343 = 0.617 µSv
Total Dose < 0.0007 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.0007mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Mn-54
Form: Solid Sealed Source (T4)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma</td><td>Energy of Principle emissions : 0.835MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 313 days</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Mn-54 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Mn-54 Source
Original Activity of Mn-54 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.43 µSv/hr
Dose Rate of 0.0043 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Mn-54 0.166 x 24 x 0.43 = 1.71 µSv
Total Dose < 0.002 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)

Mn-54 9 x 2 x 0.43 = 7.74 µSv
Total Dose < 0.008 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.008 mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Na-22
Form: Solid Sealed Source (T5)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and positron emission</td><td>Energy of Principle emissions : 1.275 MeV and 0.545 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 2.6 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Na-22 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Na-22 Source
Original Activity of Na-22 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.66 µSv/hr
Dose Rate of 0.0066 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Na-22 0.166 x 24 x 0.66 = 2.63 µSv
Total Dose < 0.003 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)

Na-22 9 x 2 x 0.66 = 11.88 µSv
Total Dose < 0.012 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.012 mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Cd-109
Form: Solid Sealed Source (T6)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma</td><td>Energy of Principle emissions : 0.022 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 464 days</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Cd-109 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Cd-109 Source
Original Activity of Cd-109 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.0114 µSv/hr
Dose Rate of 0.000114 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Cd-109 0.166 x 24 x 0.0114 = 0.27 µSv
Total Dose < 0.001 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)

Cd-109 9 x 2 x 0.0114 = 0.205 µSv
Total Dose < 0.003 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.003mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Ba-133
Form: Solid Sealed Source (T7)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma and Beta</td><td>Energy of Principle emissions : 0.356 MeV and 0.32 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 10.74 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Ba-133 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Ba-133 Source
Original Activity of Ba-133 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.184 µSv/hr
Dose Rate of 0.00184 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Ba-133 0.166 x 24 x 0.184 = 0.733 µSv
Total Dose < 0.001 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)

Ba-133 9 x 2 x 0.184 = 3.31 µSv
Total Dose < 0.004 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.004mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Zn-65
Form: Solid Sealed Source (T8)</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Gamma</td><td>Energy of Principle emissions : 1.115 MeV</td></tr>
<tr><td>Physical Half-Life [T½]: 245 days</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">1 Zn-65 source in use in the School of Physics, Clinical and Optometric Sciences

Details of Dose Rate for Zn-65 Source
Original Activity of Zn-65 = 0.037 MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 0.578 µSv/hr
Dose Rate of 0.00578 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

Zn-65 0.166 x 24 x 0.578 = 2.30 µSv
Total Dose < 0.003 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)

Zn-65 9 x 2 x 0.578 = 10.40 µSv
Total Dose < 0.011 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.011 mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

<table>
<tr><th colspan="2">Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation</th></tr>
<tr><td colspan="2">Nuclide: Sr-90
Form: Solid Sealed Source</td></tr>
<tr><td colspan="2">Physical Characteristics</td></tr>
<tr><td>Primary Radiation: Beta</td><td>Energy of Principle emissions : 546 keV</td></tr>
<tr><td>Physical Half-Life [T½]: 28.2 years</td><td>Frequency of Experiment / per year
24 times per year</td></tr>
<tr><td colspan="2">Sr-90 source in use in the School of Physics, Clinical and Optometric Sciences:

Details of Dose Rate for Sr-90 Sources

(1) SR⁹⁰-2 (Metal)
Original Activity of Sr-90 Metal = 0.185MBq
Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 16.8 µSv/hr
Dose Rate of 0.168 µSv/hr @ 1 m (without shielding)</td></tr>
<tr><td colspan="2">External Exposure
Dose laboratory technician will receive per year
10 mins handling source 24 times per year (dose limit applies to annual dose)

(1) SR⁹⁰-2 (Metal) 0.166 x 24 x 16.8 = 66.9 µSv
Total Dose < 0.07 mSv per year

Dose laboratory student will receive per experiment
9 hours handling source twice per year (dose limit applies to annual dose)
(1) SR⁹⁰-2 (Metal) 9 x 2 x 16.8 = 302.4 µSv
Total Dose < 0.4 mSv per year</td></tr>
<tr><td colspan="2">Dose Constraint
Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.4mSv/year)</td></tr>
<tr><td colspan="2">Special Precautions
Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.</td></tr>
</table>

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

Radionuclide Safety Data Sheet for 4th Year Experiments involving Ionising Radiation	
Nuclide: Carbon - 14 **Form:** Solid Sealed Source	
Physical Characteristics	
Primary Radiation: Beta	**Energy of Principle emissions** : 0.156 MeV
Physical Half-Life [T½]: 5730 years	**Frequency of Experiment / per year** 24 times per year
1 C-14 source in use in the School of Physics, Clinical and Optometric Sciences **Details of Dose Rate for C-14 Source** Original Activity of C-14= 0.37 MBq Extremity (hand) dose rate measured in µSv/hr @ 10 cm = 9.62 µSv/hr Dose Rate of 0.0962 µSv/hr @ 1 m (without shielding)	
External Exposure **Dose laboratory technician will receive per year** **10 mins handling source 24 times per year (dose limit applies to annual dose)** C-14 0.166 x 24 x 9.62 = 38.32 µSv **Total Dose < 0.04 mSv per year** **Dose laboratory student will receive per experiment** **9 hours handling source once per year (dose limit applies to annual dose)** C-14 9 x 1 x 9.62 = 86.58 µSv **Total Dose < 0.09 mSv per year**	
Dose Constraint Annual Dose Limits: 1mSv per year (Calculated Dose to Staff & 4th Year Students < 0.09mSv/year)	
Special Precautions Use tools (e.g. tongs, forceps) to indirectly handle unshielded sources and avoid direct hand contact.	

Dose Limits

Annual Dose Limit for members of the public or unclassified radiation workers is 1mSv per year above the natural background dose. All experiments involving ionising radiation carried out by the undergraduate students within the School of Physics, Clinical and Optometric Sciences in TU Dublin are such that the dose to the student will be well below this limit with the controls and procedures put in place to be followed by the undergraduate student.

Radiation Risk Assessment for the Use of the X-Ray Equipment at Technological University Dublin, City Campus

Regulation 31 of the Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019 (SI 30 of 2019) requires that the undertaking makes an assessment of the nature and magnitude of the risks of exposure to ionising radiation arising from any practice for workers and members of the public who may be affected.

Furthermore, Categorisation of Exposed Workers is required under Regulation 39 of the Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019 – SI 30 of 2019.

An 'Exposed Worker' is defined in SI No. 30 of 2019 as a person who is subject to exposure at work carried out within a work practice regulated by these Regulations and who is liable to receive doses exceeding one or other of the dose limits for public exposure, i.e. an effective dose that exceeds 1mSv per year (Regulation 27 – SI 30 of 2019).

Exposed workers can be further categorised as 'Category A' or 'Category B' workers. 'Category A' workers are liable to receive an effective dose of greater than 6mSv in a year. 'Category B' workers are exposed workers who are liable to receive an effective dose of greater than 1mSv but less than 6mSv in a year.

Regulation 39 (2) of SI 30 of 2019 requires that the categorisation shall take into account potential exposures including, where relevant, the results of any individual radiological monitoring.

The purpose of this document is to undertake a risk assessment on the X-ray equipment in use at Technological University Dublin, to determine the nature and magnitude of the risk, and to also use the results of this risk assessment to categorise the workers appropriately in accordance with the requirements of SI 30 of 2019.

Risk Quantification

Risk is assessed by looking at both the likelihood of a radiation exposure occurring and the possible consequences of such an exposure (severity). The tables below are used as a guide to quantify the risk.

1. LIKELIHOOD SCORING

Rare/Remote (1)		Unlikely (2)		Possible (3)		Likely (4)		Almost Certain (5)	
Actual Frequency	Probability	Actual Frequency	Probability	Actual Frequency	Probability	Actual Frequency	Probability	Actual Frequency	Probability
Occurs every 5 years or more	1%	Occurs every 2-5 years	10%	Occurs every 1-2 years	50%	Bimonthly	75%	At least monthly	99%

2. SEVERITY SCORING – BASED ON LIKELY RADIATION DOSE

Insignificant Dose	Dose >1 mSv per year	Dose >6 mSv per year	Dose > 20 mSv per year	Dose >100 mSv per year
1	2	3	4	5

3. RISK MATRIX

3. RISK MATRIX	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Almost Certain (5)	5	10	15	20	25
Likely (4)	4	8	12	16	20
Possible (3)	3	6	9	12	15
Unlikely (2)	2	4	6	8	10
Rare/Remote (1)	1	2	3	4	5

4. RISK RATING

1-5 (Green) = Low Risk
6-12 (Orange) = Medium Risk
15-25 (Red) = High Risk

Details of X-Ray Equipment: Technological University City Campus

Equipment Type: Rigaku MiniFlex 600 X-Ray Diffraction (XRD) Inspection System. Operates at a maximum kV of 40 kV and a maximum current of 15 mA.
Equipment Location: The X-ray equipment is located in a secure location at B.09.0 FOCAS Research Institute.
This location has secure access to authorised persons only.
This X-ray machine is a 'cabinet type' system, i.e. integrally shielded and interlocked, with no significant radiation dose detectable external to the cabinet. Manufacturer's specifications state that the radiation dose will be no greater than 1 microsivert per hour at the surface of the cabinet.

Equipment Type: Bruker Tracer 5g X-Ray Fluorescence (XRF) Analyser. Operates at a maximum kV of 50 kV and a maximum current of 0.195 mA.
Equipment Location: The X-ray equipment is located in a secure location at B.18.0 FOCAS Research Institute
This location has secure access to authorised persons only.
This X-ray machine is a trigger switch operated and password protected handheld XRF analyser, with no significant radiation dose detectable when in operation. Manufacturer's specifications state that the radiation dose will be no greater than 1 microsivert per hour at the surface of the cabinet.

Equipment Type: Leybold Didactic X-Ray System. Operates at a maximum kV of 35kV and a maximum current of 1mA.
Equipment Location: The X-ray equipment is located in a secure location at CQ123, Central Quad, Grangegorman
This location has secure access to authorised persons only.
This X-ray machine is a 'cabinet type' system, i.e. integrally shielded with beam and door interlocks, with no significant radiation dose detectable external to the cabinet. Manufacturer's specifications state that the radiation dose will be no greater than 1 microsivert per hour at the surface of the cabinet.

Risk Assessment

Activity	Hazard - Exposure to Ionising Radiation	Likelihood (L) x Severity (S) No Controls	Risk Potential Dose No Controls Exceptional Circumstances Accident / Incident	Controls	Likelihood(L) x Severity (S) Controls in Place	Risk Expected Dose Planned Exposure All Control Measures in Place
Use of X-Ray Equipment	Potential external exposure to ionising radiation from X-rays	L = 3 S = 5	15 (High)	The X-ray cabinet type equipment is integrally shielded and guarded with lead and stainless-steel shielding built into the equipment. Cut out interlocks are fitted to the equipment to prevent access to the X-ray beam. The integral shielding ensures that the external radiation dose rate is insignificant. The hand held XRF operator must ensure that the equipment is always attended when in use and that other persons are kept away from the equipment when it is in operation >1m distance. They must keep the metal window on the side of the unit faced away from the body during use. The XRF proximity sensor will be switched on at all times, ensuring that x-rays will not be	L=1 S=5	5 (Low)

				emitted if there is no sample covering the proximity sensor. All manufacturer's specifications advise that the machines have been designed to ensure that radiation doses external to the equipment are below 1 microsievert per hour. This low dose rate indicates that there is no need to classify work areas as Controlled or Supervised areas, nor is there any requirement for personal monitoring of employees. All X-ray equipment have warning lights to indicate when the system is powered on and when the X-ray is actually on. All X-ray equipment can be easily switched off using an emergency stop button and / or isolator switch. Only trained and competent persons are authorised to use the X-ray equipment. Employees using the X-ray equipment are aware that one must never place their hand or any part of their body into the inspection chamber/beam when X-ray is on. Signage is in place on the equipment to indicate that it is capable of producing ionising radiation. All X-ray equipment is located in areas with secure access to authorised persons only.		

				Only authorised persons may use the X-ray equipment. The X-ray equipment will be serviced and maintained on an annual basis by a competent service engineer to ensure that the safety features of the equipment are operating satisfactorily and that radiation doses are insignificant. Operators of the equipment are aware that should they notice any faults in the equipment that may affect the safety of the machine that they should cease using the machine immediately and have it repaired by a competent service engineer. Modifications or repairs will never be undertaken by persons who are not competent service engineers. Radiation Safety Procedures have been compiled which must be complied with in the use of this equipment.		

Risk Quantification – Potential Doses without Operational Controls (Exceptional Circumstances)

Hazard: Exposure to Ionising Radiation

Persons at Risk:

- Employees using the equipment
- Public, Contractors or Employees in the vicinity of the equipment

Risk: High Based on 5x5 risk matrix above

Likelihood: 3

Severity: 5

Overall Risk: 15

Result: High Risk

Explanation: Employees may receive radiation doses to the skin, if this equipment is not used in the correct manner from:

Exposure to main beam

Exposure to x-ray scatter

Exposure to x-ray leakage

With no operational controls in place it is possible that an individual could receive a very significant radiation dose from the primary X-ray beam. The dose in the primary beam is in the order of Sieverts per hour. Exposure in the direct line of the primary beam could lead to a radiation dose that may result in a burn to the skin

Risk Quantification – Planned Exposures - Expected Doses with Operational Controls

Hazard: Exposure to Ionising Radiation

Persons at Risk:

- Employees using the equipment
- Public, Contractors or Employees in the vicinity of the equipment

Risk: Low, Based on 5x5 risk matrix above

Likelihood: 1

Severity: 5

Overall Risk: 5

Result: Low Risk

Explanation: With all operational controls in place it would be rare (occurs less than every 5 years) that any individual may receive a radiation dose of any significance. The radiation dose external to the equipment is guaranteed to be less than 1 microsievert per hour, in accordance with the manufacturer's specifications.

Classification of Workers Based on Results of this Risk Assessment

Taking the above dose estimates and quantified risk assessments into account it is considered unlikely that an employee would exceed the annual radiation dose limit for a member of the public of 1 mSv when control measures are implemented. Workers using the X-ray equipment therefore do not need to be categorised as 'Exposed Workers' and personal dosimetry monitoring is not required.

Note: This risk assessment and the categorisation of workers should be kept under review and may be subject to change based on factors such as future monitoring results, changes in the nature or type of work or sources of ionising radiation and ongoing training of current and new employees.

Categorisation of Work Areas Based on Results of this Risk Assessment

The work areas in which the X-ray equipment are used do not need to be categorised as 'Controlled Areas' or 'Supervised Areas' in accordance with the definitions and requirements for such an areas as specified in the Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019. It is important though that access to the equipment is restricted to authorised persons through key control and password protection on the equipment as relevant.

Prepared by:

Date:

RISK ASSESSMENT FORM – For information only (currently no unsealed sources in use in TU Dublin)

Company Name: Technological University Dublin

Company Address: Central Quad, TU Dublin City Campus, Grangegorman Lower, D07 ADY7

Assessment Completed by: Jane Torris **Date**: 20-04-2021

Hazard	Persons at risk	Methods of Reducing Risk from Hazard	Risk from hazard		
			High	Med	Low
Uranium Salts – Uranyl Acetate Unsealed Source Inhalation or ingestion of material leading to • Irradiation of lungs or bone cells which could result in lung or bone cancer. • Chemical damage to kidneys and the production of necrotic arterial lesions.	Staff of the Radiation and Environmental Science Centre (RESC)- FOCAS Research Institute	Warning signs indicating that ionising radiation is in use. Training and radiation protection awareness. <u>Special Precautions:</u> 1) The preparation of the working solutions from dry powder Uranyl Acetate must always be performed in a fume cupboard. 2) Stock jars will always be opened in a fume cupboard in case of a buildup of radon gas. 3) Staining operations will be performed over trays covered with absorbent paper. 4) PPE – Safety glasses, laboratory coat and gloves must always be worn when handling the stock jars.		X X	