

X-RAY Safety Manual

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University Emergency Contacts

24 Hour Emergency:

Emergency Contacts	Telephone
St. John's Campus	864 - 4100
Health Sciences Centre	864 - 4100
Marine Institute	778 - 0456
Grenfell Campus	637-2888
Ocean Sciences Centre	864 - 4100

Department of Health and Safety

General Contacts	Telephone	Email	Fax
Radiation and Biosafety	864-8250	rso@mun.ca	864-3116
Control Officer			
Associate Director	864-6126	health.safety@mun.ca	864-3116
Environmental Health and			
Safety			

Website: <u>http://www.mun.ca/health_safety</u>

ACRONYMS

ALARA	As Low As Reasonably Achievable
ALI	Annual Limit of Intake
CNSC	Canadian Nuclear Safety Commission
DCP	Dosimetry Contact Person
EHS	Environmental Health and Safety
μSv	Microsievert
MUN	Memorial University of Newfoundland
NEW	Nuclear Energy Worker
PI	Principal Investigator
RSO	Radiation Safety Officer
XED	X-ray Emitting Device
XSP	X-ray Safety Program
URSC	University Radiation Safety Committee

1.0 Introduction

At Memorial University of Newfoundland (MUN), analytical x-ray emitting devices (XED's) are used for teaching and research purposes. X-rays are a type of ionizing electromagnetic radiation identical to gamma radiation. By convention gamma radiation references emissions that result from nuclear decay or rearrangement. X-rays refer to radiation that results from deceleration of a charged particle in an atomic field (broad-spectrum x-rays) or from electronic rearrangement following expulsion of a lower shell electron by an external charged particle (characteristic x-rays). Thus, x-rays normally refer to electromagnetic radiation produced using a charged-particle (e.g. electrons) accelerator often called an x-ray generator. X-rays pose an external radiation hazard.

The use of X-ray emitting devices is regulated through the Government of Newfoundland and Labrador under the <u>Radiation Health and Safety Act</u> and <u>Regulations</u>. Use of X-ray emitting devices must also comply with the Government of Canada's <u>Radiation Emitting Devices Act</u> and <u>Regulations</u>, and <u>Health Canada's Safety</u> <u>Code 32 (and addendum)</u>.

2.0 X-ray Use at MUN

The generation of X-rays for use in analytical X-ray equipment is accomplished by the collision of high energy electrons with a metal target in a vacuum tube. A high voltage is applied between the cathode and anode in the X-ray tube. Thermionic emission frees electrons at the cathode that are then accelerated to the anode using a high voltage field (20 - 150 kVp). The interaction at the anode produces both characteristic and broad spectrum x-rays. The composition of the anode determines the spectrum of x-rays produced. A variety of metals are used as target material including tungsten, iron, gold, chromium, cobalt, molybdenum and copper. The collision produces heat that is removed by the cooling system and X-rays that exit through a beryllium (e.g) window that faces the intended target. When the high voltage to the X-ray tube is turned off X-ray production ceases. X-ray production is used for a variety of purposes at MUN:

2.1 X-ray Diffraction (XRD) Equipment

X-ray diffraction (XRD) analysis is based on the principle that X-rays can undergo elastic collisions with atoms, known as Thomson and Raleigh scattering, which change the direction of the X-ray photon without changing its energy. The change in the direction of the X-ray photon depends in a complex way on the target atom and its structural relationship to other atoms in the sample. Different compounds produce different X-ray diffraction patterns and by analyzing the type of X-ray diffraction pattern produced, the structure and identity of the material under analysis can be determined.

The X-rays which are produced are sent through a device called a goniometer which consists of a shutter, attenuation filters, a sample chamber, and a mechanism for rotating the sample in an arc relative to the X-ray beam. As the X-ray beam strikes the sample it is diffracted at discrete angles characteristic of the material in the sample. The specific angles of diffraction are determined by a detector connected to an arm on the goniometer which rotates the detector in an arc around the sample. The detector sends an electronic signal to a data processor whenever radiation is detected. The data processor in turn, produces a spectrograph of radiation pulses versus angle of rotation and this can be compared to a spectral library to determine the structure and identity of the sample.

X-ray diffraction analyses typically make use of the mono-energetic X-rays. X-rays of other energies such as white radiation (Bremsstrahlung radiation) interfere with the analysis process. Since white radiation increases

with the atomic number of the target used, use of a lower atomic number target such as cobalt or chromium will produce less white radiation than would be produced by a higher atomic number target such as tungsten or gold. The white radiation that is produced can be further reduced by the use of filters that selectively attenuate this radiation.

To reduce exposure to the operator from radiation scattered off the sample and other components in the beam line, the sample chamber and beam line are enclosed within metal covers and conduits which prevents radiation leakage from inside of the goniometer. Another design feature which protects the operator from both scatter and direct radiation are shutters that block the primary X-ray beam from reaching the sample chamber during sample replacement.

Although lead is commonly used for attenuating high energy photon radiation, lower atomic number material such as steel can be used for lower energy X-rays. The design goal of shielding is to maintain leakage, secondary and primary radiation emissions below the allowable rate (0.5 uSv/h).

Another design feature which protects the operator from radiation exposure is a transparent, lead acrylic enclosure around the diffraction equipment which has sliding doors interlocked with the x-ray tube power supply to prevent inadvertent access to high radiation areas. If the sliding doors are opened while the X-ray tube is energized or the shutter is open, a magnetic switch on the door is activated which automatically shuts off the X-ray tube. This interlock feature can be defeated using a key switch on the control panel during times when the beam must be left on while the operator is inside of the enclosure such as during beam alignment. However, having a removable key to operate the switch provides a measure of administrative security over this interlock.

2.2 X-ray Fluorescence (XRF) Spectrometers

Whereas X-ray diffraction equipment is used to determine the microstructure of matter, X-ray fluorescence (XRF) spectrometers are used to determine its elemental composition. This technique capitalizes on the characteristic fluorescence spectrum each element produces when excited by X-rays. X-rays are absorbed by electrons in the inner K and L shells of atoms which causes electrons to be ejected from the atom (ionization) and results in vacant inner orbitals. Fluorescence is the emission of photons following electron transitions from high energy to vacant low energy orbitals of the ionized atom.

Each element produces a spectrum of fluorescence photons which is characteristic of the element and therefore can be used to identify the element. The energies of the photons emitted from the sample are determined using a radiation detector connected to a multi-channel analyzer. The radiation detector converts the photons emitted from the sample into pulses of electrical current. The amplitude of each electrical pulse produced is proportional to the energy of the emitted photon and by separating the electrical pulses according to their amplitude the system's digital analyzer determines the energy spectrum of the radiation emitted from the sample undergoing fluorescence.

Unlike XRD equipment which requires low energy, X-rays for analysis of the compound, XRF spectrometers utilize poly-energetic X-rays to excite and ionize atoms in the sample to be analyzed. This allows for a somewhat simpler design in that the elimination of X-rays of certain energies is not required as it is for XRD analysis. However, the disadvantage is that any scatter or leakage radiation will also consist of higher energy, more penetrating X-rays that will require lead as the shielding material. The use of other types of

material such as iron or aluminum will not be as effective in shielding X-ray spectrometers as it is for shielding the low energy X-rays used in XRD equipment.

To reduce the hazard from the high energy X-rays, XRF spectrometers have a lead shielded, closed design that eliminates the need to gain personal access to the X-ray beam. Overall, this makes XRF spectrometers somewhat safer than XRD equipment, where close access to the beam is possible. However, special hand-held XRF devices contain an open port from which collimated, high-intensity primary beams emerge and require the use of other controls to minimize the dose received by the operator.

2.3 Cabinet X-ray Equipment

Cabinet X-ray equipment is used to determine the existence of heterogeneities in the structure of a sample. This is generally accomplished by acquiring an X-ray radiograph, although other imaging techniques may also be employed.

The sample is placed between the source of X-rays and the 2D detector and an image of the sample is acquired. Any heterogeneities in the sample will appear on the film as light or dark spots depending on the difference in X-ray absorption between the heterogeneity and the rest of the sample. For example, cracks in the sample will allow more radiation to pass through and this will be seen as a dark spot in the image since the degree darkening is proportional to the degree of radiation exposure.

Cabinet X-ray equipment generally has a box-like design consisting of the following components:

- shielded interior cabinet
- X-ray tube
- beam collimator
- detector (typically flat plate style)
- shielded access doors and panels
- control panel which includes
 - key switch to enable energizing the X-ray tube
 - o on/off switch for X-ray production
 - o "power-on" warning light
 - o "X-rays-on" warning light
- safety interlocks on the door and exterior panels

In order to penetrate relatively thick or dense samples such as rock or pieces of metal, intense, high energy X-rays must be used to take the radiograph. This also means that more lead is required to shield the equipment which would otherwise leak radiation to the surroundings. However, cabinet X-ray equipment must be designed to meet minimum standards of radiation leakage (~ 4.39 uGy/h at 5cm) and generally this equipment will not pose a radiation hazard to the operator if maintained properly.

The main concern is that access to the interior of the cabinet must be prevented while a specimen is radiographed thereby preventing exposure to the direct beam. This is accomplished by designing the equipment with an electrical interlock which prevents X-rays from being generated while the cabinet door is open - similar to the system used on microwave ovens.

3.0 Organization & Administration of X-ray Safety

3.1 Purpose and Scope

This manual applies to all members of the university community (including, but not limited to: faculty, staff, students and external contractors) that <u>work with or around</u> X-ray emitting devices, including during repair or beam alignment in any facilities controlled by MUN.

This manual, in conjunction with provincial and federal regulations, provides the framework for creating a safer environment for all individuals at MUN.

3.2 Health and Safety Policy

Memorial University of Newfoundland strives to provide an incident and accident free environment. The university believes that health and safety is a shared responsibility but recognizes that the Employer is ultimately responsible for the health and safety of all members of the university community.

The President ensures that a Health and Safety Management System is documented, implemented and maintained.

All Members of the university community have an individual responsibility to integrate health and safety practices into their daily activities. Members of the university community are also required to take reasonable care to protect their own health and safety and that of other persons at or near the workplace.

Every supervisor is responsible for fulfilling the requirements of the university's Health and Safety Management System (HSMS). They are also responsible for taking every reasonable precaution to protect and promote the health and safety of those workers under their supervision.

The University Radiation Safety Committee (URSC) is established under the authority of the President. The URSC is authorized by the President to advise in the safe use of X-ray emitting equipment, make recommendations on policies, and approve procedures and guidelines. In accordance with the University's administrative framework and on the recommendations of the URSC, the university's Environmental Health and Safety (EHS) shall administer the X-ray Safety Program (XSP). EHS has the authority to enforce university policies and regulatory standards.

3.3 ALARA Principle

ALARA is an acronym for <u>As Low As <u>R</u>easonably <u>A</u>chievable. This principle means making every reasonable effort to maintain exposures as far below the regulated dose limits as is practical. ALARA is consistent with the purpose for which X-ray use is undertaken it takes into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to state of technology, the economic considerations in relation to utilization of X-rays in the public interest.</u>

It is MUN's practice that exposure to ionizing radiation will be far below the regulated dose limit. Exposures will be limited by utilizing strict policies or procedures, ensuring worker training, well maintained facilities and personal protective equipment (PPE). MUN is committed to minimizing radiation exposure to staff, students, and the public that may result from the use of X-ray emitting equipment in diagnostic and research procedures. The URSC and the Radiation Safety Officer (RSO) will advise and assist in all matters of X-ray safety. The URSC will recommend to the university administration the policies and procedures to be required for minimizing and monitoring exposure.

3.4 University Radiation Safety Committee (URSC)

The purpose of the URSC is to ensure that all nuclear substances and radiation devices authorized under MUN's NSRD license are used with proper consideration for the health and safety of staff, researchers, volunteers, visitors and the public, as well as protection of the environment. This committee is responsible for the oversight and administration of the University's Radiation Safety Program (RSP) and functions according to its Terms of Reference (TOR). All practices will be in conformity with CNSC regulations and all other provincial and federal radiation-related legislation and regulations.

3.5 Roles and Responsibilities for X-Ray Safety

3.5.1 URSC

The URSC is responsible for the development of all policy related to X-ray safety, including but not limited to: equipment purchasing, registration, safety, training, disposal and environmental protection.

The URSC is also responsible for monitoring the implementation of its policy as per the committee's terms of reference.

3.5.2 Executive and Senior Management

The senior management of the university will ensure that adequate funds and resources are provided to run the X-ray safety program effectively. Furthermore, the senior management will provide support for X-ray safety in operations.

Although the ultimate responsibility for X-ray safety within the university and affiliated institutions lies with the President, information and concerns regarding X-ray safety are communicated through the vice-president (administration and finance).

The vice-president (administration and finance) appoints members to the URSC in consultation with appropriate Deans or Directors, and approves the terms of reference for the URSC in consultation with the vice-president (research).

3.5.3 Radiation Safety Officer

The RSO is delegated the authority to administer all aspects of the X-ray safety program. The RSO has the authority to suspend operations in the cases where he or she perceives an immediate threat to health, safety, or the environment.

The RSO shall:

- Ensure that X-ray emitting equipment is installed in accordance with Safety Code 32 and its addendum.
- maintain contact as necessary with Service NL of the Government of Newfoundland and Labrador, and ensure all information and reports required by legislation are submitted;
- make evaluations (e.g., concerning the applications for equipment registration, suitability of space, equipment, disposal, safe practices, training) and make recommendations regarding these to the URSC;

- suspend the use of X-ray emitting devices by any person when, in the judgment of the RSO, the safety of any person or the environment is in jeopardy. Such suspension will be reported to the URSC Tier II committee as soon as possible;
- investigate and, where necessary, supervise after accidents or incidents involving X-ray emitting devices, and report the event to Service NL of the Government of Newfoundland and Labrador and to the chair of the URSC;
- investigate any incidents involving X-ray emitting devices or exposures over the dosimetry action level recorded on dosimeters;
- arrange to provide radiation/X-ray safety training for staff and students who wish to use X-ray emitting devices at the university, and ensure all users of X-ray emitting devices are appropriately trained;
- ensure radiation detection equipment is obtained, maintained and calibrated as required;
- submit other reports as requested and prepare regular updates for URSC meetings;
- maintain an inventory of all X-ray emitting devices owned by MUN;
- manage the decommissioning and disposal of all X-ray emitting devices at the university;
- oversee the dosimetry program and report all exposures as required;
- provide on-going advice and technical assistance to persons using X-ray emitting devices at the university;
- provide recommendations for the radiation safety budget;
- maintain records required by Service NL of the Government of Newfoundland and Labrador;
- conduct laboratory inspections/audits to confirm compliance to regulatory requirements and codes;
- attend meetings of the URSC;
- conduct other related duties as requested by the URSC.

3.5.4 Administrative Heads

The Administrative Head has the following responsibilities within the program:

- Identify all principle investigators utilizing X-ray emitting devices under his/her authority and ensure that they clearly understand their duties and responsibilities as individuals with principle authority for X-ray emitting devices;
- Ensure that all components of the XSP are implemented in the department.

3.5.5 X-ray Emitting Device Responsible User

These responsibilities extend to all corporations, contractors, onsite personnel, or research laboratories. The Responsible User will be the person listed on the registration certificate issued by Service NL. Responsibilities of the Responsible User include:

- Initiating registration procedures for all X-ray emitting devices before use and de-registering any decommissioned pieces of equipment with the RSO;
- ensuring compliance with X-ray safety policies, procedures and codes as they are outlined in this X-ray safety manual;
- Providing and enforcing the use of appropriate personal protective (PPE) equipment when required;
- reporting incidents or concerns to the RSO;
- responding to inspection reports;
- implementing a system of verification, supervision and periodic review to ensure that all users and maintenance personnel have received adequate training and have read and understood this manual, the

applicable radiation safety rules, safe operating and emergency procedures before using and/or servicing the X-ray equipment;

- prescribing and posting prominently near the X-ray equipment radiation safety rules and safe operating and emergency procedures which shall include address information and contact details of a hospital or clinic where medical treatment can be administered; ensuring any corrective actions required are implemented;
- receiving suggestions on changes and improvements to radiation safety procedures and practices in the interest of ALARA;
- Assuming the role of, or designating a Dosimetry Contact Person (DCP) who will liaise with the RSO. (Note: in the absence of a DCP, the Responsible User will automatically serve as the liaison);
- providing cost coverage for dosimetry service when replacement or late fees are incurred;
- providing an appropriate survey meter and ensuring that it is in a working and functional condition at all times for use by users and maintenance personnel;
- establishing a maintenance program, taking into account the age and frequency of use, that ensures all safety devices and components critical to both X-ray production and shielding are routinely checked and defective parts replaced or repaired;
- make readily available a copy of this manual, the NL Radiation Health and Safety Act and Regulations, Government of Canada's Radiation Emitting Devices Act and Regulations and Health Canada Safety Code 32 (and addendum) for reference by users and maintenance personnel.

3.5.6 X-Ray Equipment Supervisors

The Equipment Supervisor is an individual who is delegated supervisory responsibility for X-ray emitting devices and/or X-ray workers by the Responsible User. The Equipment Supervisor may take over responsibility for some or all of the responsibilities outlined under Responsible User in this manual.

3.5.7 Authorized X-Ray Workers

Individuals who may use, manipulate, or handle X-ray emitting devices such that he/she could receive a measurable annual radiation dose, above the background level as identified by Service NL and the CNSC are considered Authorized X-ray Workers. All Authorized X-ray Workers including faculty, staff, students, physicians, volunteers, contractors shall:

- receive training on X-ray safety authorized by the RSO <u>prior</u> to commencing work with X-ray emitting devices;
- receive specific training on the device prior to commencing work;
- have read, understood and follow all applicable radiation safety rules, codes and emergency procedures that are prescribed by the equipment supervisors and by the RSO;
- be authorized by the Responsible User <u>AND</u> the RSO to use X-ray emitting devices;
- follow all applicable procedures in this X-ray safety manual;
- wear prescribed radiation dosimeters at all times while working with or around X-ray emitting devices;
- use an appropriate survey meter to identify and monitor radiation levels at critical areas (tube housing, beam ports, shutters, analysis accessories, etc.) of the equipment during set up. They must also beam alignment procedures, follow modifications and alterations to the device or its accessories, ensure that compliance with the regulatory limit (~4.3 μ Sv/hr at 5 cm from any external surface of the equipment) is maintained, and that the guidance levels including the permissible dose limits would not be exceeded under routine operational conditions of the equipment;

- conduct the pre-operational safety checks indicated in <u>Section 5.2.2</u> of this manual;
- follow the guidance and direction provided by EHS staff;
- stop the operation of an X-ray emitting device and inform their managers or supervisors anytime they believe a procedure involving an X-ray emitting device is inappropriate, impractical, incorrect or dangerous;
- report incidents (*e.g.* accidental exposure) to their supervisors **<u>and</u>** the RSO;
- report non-compliances, defects in X-ray emitting devices or radiation safety devices, loss of control of X-ray emitting devices, and acts of sabotage to the immediate supervisor **and** the RSO;
- follow directives given by their manager, supervisor, and/or RSO to implement means of reducing radiation exposure according to ALARA.

3.5.8 Dosimetry Contact Person

Where dosimeters are assigned or mandated, the Responsible User or department of the Responsible User shall designate, in consultation with the RSO, a person who is responsible for their work area to:

- ensure that all new personnel working with X-ray emitting devices complete and submit an X-ray worker registration form;
- coordinate dosimeter requests and handling;
- ensure area supervisor(s) receive dose reports;
- report any suspicions or observations of dosimeter non-compliance to his or her supervisor.

3.5.9 Maintenance Personnel

Maintenance personnel are individuals who are trained and authorized to perform alignments, upkeep, maintenance or repairs of analytical and cabinet X-ray equipment. All maintenance personnel shall:

- be adequately trained in the maintenance and repair of the X-ray equipment for which they are responsible, with emphasis on maintenance operations that may require X-ray production;
- have read, understood and be able to follow all radiation safety rules, requirements, and emergency procedures applicable to the X-ray emitting device and facility, including the guidelines on operational safety and exposure monitoring;
- Wear radiation dosimeters to monitor separately whole body and extremity doses as deemed appropriate for the operation(s) being undertaken;
- Use a radiation survey meter to identify and monitor the radiation levels at critical areas (tube housing, beam ports, shutters, analysis accessories, etc.) of the equipment during set up, beam alignment and maintenance, and following modifications to the device or its accessories;
- Undertake precautionary measures to eliminate or reduce radiation levels (measure according to the preceding clause) to ensure that the regulatory limit (~4.3 μ Sv per hour at 5 cm from any external surface of the equipment) is met, and that guidance levels including the permissible dose limits would not be exceeded during routine operational conditions of the equipment;
- Perform regular reviews of their own personal dosimetry data and identify unexpected radiation exposures, investigate them to determine the root cause(s) and implement appropriate corrective actions(s) as may be necessary;
- Provide the user and the equipment owner or designee with a written report that specifies explicitly any user procedure or action that could lead to an X-ray hazard, as soon as such a procedure or action is identified;
- Adhere to the maintenance safeguards outlined in this manual (<u>section 5.2.3</u>);
- Supervise the work of maintenance personnel in training;

• Prevent the operation of the analytical X-ray emitting device if any unsafe operational conditions arise, and immediately notify the Equipment Supervisor and RSO.

3.5.10 Health Physicist

A health physicist is available to consult with the URSC at the request of the chair or in an emergency situation at the request of the RSO or the Associate Director of Environmental Health and Safety.

3.5.11 Environmental Health and Safety (EHS)

The RSO provides administrative support for the URSC and the functions of the X-ray Safety Program. The Associate Director of EHS is an *ex officio* member of the URSC Tier I committee and communicates with the vice-president (administration and finance) at the request of the URSC or as appropriate to maintain the radiation safety program.

3.5.12 Campus Enforcement and Patrol

Campus Enforcement and Patrol (CEP) provides security related to the radiation safety program (including X-ray safety program) and provides communication and support for emergencies and incidents related to radiation safety. CEP services are available 24 hours per day for this purpose. CEP maintains emergency contact information that is supplied by the RSO. A member of CEP serves on the URSC Tier I committee.

4.0 Procedures

4.1 X-Ray Safety Training

Authorized XED users are required to complete the X-ray safety course administered by EHS **prior** to commencing work with X-ray emitting devices. Refresher training shall be completed every five (5) years and can be requested via: <u>http://www.mun.ca/health_safety/training/</u>

The online X-ray safety course is designed to provide basic information pertaining to the characteristics of radiation, biological effects, review of units and calculations, means of reducing exposure (ALARA), emergency procedures and other procedures and policies associated with MUN's XSP.

In addition, each user must receive additional in-house training pertaining to the specific characteristics and risks associated with the X-ray procedures to be used in the laboratory, how to reduce exposure while working in the laboratory, and how the requirements of the XSP are implemented and complied within the laboratory. This training must be provided by the Responsible User or a qualified delegate. All in-house training shall be documented in a **training log** (Appendix 1). Records for worker training must be maintained by the permit holder and be made available for inspection.

4.1.1 Authorized X-Ray Workers

- Before using any X-ray emitting device, new users shall:
 - complete an X-ray Worker Registration Form (Appendix 2);
 - complete the online X-ray safety training course (completion date to be entered on X-ray Worker Registration Form);
 - receive the additional in-house training specified in <u>section 4.1</u>;
 - Demonstrate proficiency in using the x-ray device
 - receive any necessary dosimeters from the dosimetry contact person for the XED;

• be added to the Responsible User's authorized X-ray worker list by the RSO.

4.1.2 **Responsible Users**

Responsible Users shall ensure that:

- all authorized X-ray workers have completed the online training, received additional training as per <u>section</u> <u>4.1</u>. and received any required dosimeters;
- all users are aware of any pertinent information regarding X-ray safety and laboratory specific procedures;
- all users are made aware of any changes in policies and procedures of the University.

4.2 Purchase or Installation of X-Ray Emitting Devices

Newly purchased equipment or equipment that has been changed in any way (physical modifications, change of location, change of use, etc.) must be certified as safe to use and registered with the Government of NL **prior** to any work with the device. After installation, an inspection must be completed <u>by the installer</u> where device safeguards, dose rates, etc. are tested/measured to verify that the device and its set-up is compliant with all federal and provincial regulations. An inspection report indicating that the device and its set-up are acceptable shall be obtained by the Responsible User and forwarded to the RSO prior to the commencement of any work with the device.

4.2.1 Registration of X-Ray Emitting Devices

All XED's at MUN must be registered with EHS and Service NL of the Government of Newfoundland and Labrador annually under the Newfoundland Radiation Health and Safety Act and Regulations. Up to date registration stickers shall be posted near the XED. Any changes to equipment, location or purpose of use will require re-certification by Service NL. Work with XED's is not permitted without a valid registration certificate (sticker). For newly installed equipment, the following documentation is required for registration:

- Completed registration form (obtained through the RSO);
- Manufacturer provided documents indicating that the device is compliant with Canadian X-ray safety legislation;
- A copy of the operational manual;
- Installer's inspection report (see <u>section 4.2</u>).

X-ray sources that operate at <u>**1 MeV and above**</u> are subject to licensing and enforcement by the Canadian Nuclear Safety Commission (CNSC). Contact the RSO if you plan on purchasing equipment that satisfies this requirement.

4.3 Radiation Dosimetry

Authorized X-ray workers shall register for the dosimetry program and wear a personal dosimeter <u>at all</u> <u>times</u> while working with or in the vicinity of XED's. Two types of dosimeters are available:

- Dosimeters designated "Body" are used to measure the actual radiation dose absorbed by the body (effective dose) and monitor occupational risk.
- Dosimeters designated "Extremity" (e.g. neck/collar, ring/finger, wrist) are used to measure the radiation exposure to the extremities of the body and to monitor non-uniform radiation exposure.

Dosimeters are exchanged on a regular basis (i.e. quarterly). A national dosimetry registry is maintained by Health Canada's National Dosimetry Services (NDS). The effective dose received is measured in

miliSieverts (mSv). The RSO will review all Health Canada dose reports and provide a written report to any Nuclear Energy Worker (NEW) who receives a measurable dose.

4.3.1 Exposure Limits

The CNSC regulates the allowable radiation dose received by workers. Anyone in a position where there is a possibility that they may receive a dose higher than that allowed for members of the public must be classified as a Nuclear Energy Worker (NEW).

MAXIMUM PERMISSIBLE ANNUAL DOSES LEVELS				
	Member of the General Public	Nuclear Energy Worker*		
	(Non-Nuclear Energy Worker)	(NEW)		
Whole body, gonads,	1 mSv	50 mSv^{**}		
bone marrow				
Skin, thyroid, bone	50 mSv	500 mSv		
Hands, feet and	50 mSv	500 mSv		
forearms				

SORL2000-203 – Nuclear Safety & Control Act Radiation Protection Regulations.

- *A Nuclear Energy Worker is defined as anyone who, in the course of his or her work could exceed the dose limit for a member of the general public. Based on research design, historical records and anticipated dose, an individual will be identified and will be formally required to sign the appropriate documentation (available from the RSO). Therefore, the RSO must be informed of any experimental design where an increased dose is anticipated. Pregnant NEW's are further restricted to 4 mSv for the balance of their pregnancy.
- **The 50 mSv limit is for a single year in five. The maximum permissible WB dose is 100 mSv in five years or 20 mSv/y. This latter figure is also the design specification for occupational health.

4.3.1.1 **Pregnant Radiation Worker**

A special situation arises when a radiation worker becomes pregnant. Under these conditions, radiation exposure could also involve exposure to the embryo or fetus. Any authorized X-ray worker who becomes aware that she is pregnant shall <u>immediately</u> inform the RSO in writing. The RSO and permit holder will then determine appropriate accommodations to limit further doses to the worker.

4.3.1.2 Action Levels

If a reported quarterly dose received by an authorized X-ray worker (non-NEW) exceeds <u>0.3 mSv</u>, the RSO will:

- 1. Initiate an investigation to determine the cause of the elevated dose;
- 2. Make recommendations to help minimize further doses related to the type of activity or research that led to the exposure.

4.3.1.3 Unintended X-ray radiation exposure

When an unintended or inappropriate X-ray radiation exposure occurs resulting in a much greater dose than was planned, an incident report will be filed through <u>Memorial's Incident Management System (MIMS)</u>.

Unintended or inappropriate exposures might occur:

- From operating an XED without a shield,
- From occupying an area while a XED is active without use of personal dosimetry,
- From inadvertent exposure to an embryo/fetus,
- following prolonged (low rate) radiation exposure.

An unintended or inappropriate exposure report should include:

- Name and contact information for the individual exposed,
- Date(s) of exposure,
- Location of exposure,
- Type of XED,
- Brief description of incident.

4.3.2 Survey Meters

All locations where XED's are used will have an appropriate survey meter (or access to an appropriate survey meter) to:

- Identify and monitor radiation levels at critical areas (tube housing, beam ports, shutters, analysis accessories, etc.) of the equipment during set up and beam alignment procedures, and following modifications and alterations to the device or its accessories;
- Ensure that compliance with the regulatory limit (~4.3 μ Sv/hr at 5 cm from any external surface of the equipment) is maintained, and that the permissible dose limits would not be exceeded under routine operation conditions of the equipment.

4.4 X-Ray Signage

The outside of each room containing XED's will be permanently affixed with the appropriate X-ray warning sign. The sign must be clearly legible and visible at a distance of 2 meters to individuals approaching the room door (see example below).



In addition, each XED must have the appropriate signs indicating that X-rays are being produced, as per the Radiation Emitting Devices Act and Health Canada Safety Code 32. The control panel of each piece of equipment must indicate when each X-ray tube is energized **and** when X-rays are being produced. In addition, separate flashing warning lights shall be mounted near each X-ray tube in such a way as to be clearly visible from any direction, which indicate when X-ray tubes are energized **and** when X-rays are being produced. Warning indicators must also indicate when shutters are open or closed.

4.5 Compliance and Enforcement

4.5.1 X-Ray Safety Inspections

X-ray Safety Manual, XSM v1 Date of first issue: Sept 2016 X-ray emitting device safety inspections are required periodically to ensure safe operation of the device and compliance with MUN's X-ray safety program and all applicable regulations. Responsible Users shall conduct internal X-ray safety inspections and submit the results to the RSO no later than <u>June 30</u> each year. The X-ray safety inspection checklist can be found in Appendix 3.

The RSO will perform periodic audits of all registered XED's with consultation with the Responsible User. Any necessary measures required to improve the safety of XED's and/or the operating procedures in place will be relayed to the Responsible User with a due date by which implementation of corrective action is required.

Failure to comply with provincial and federal regulations and/or university policies and procedures may result in cancellation of the registration certificate and suspension of work activities (subject to review by the URSC).

4.6 Records

The following records shall be maintained by the XED Responsible User indefinitely:

- Registration Certificates/Stickers;
- Compliance verification reports/documents;
- Internal audits and inspection reports;
- Maintenance and service records;
- Accident and investigation reports;
- List of Authorized X-ray Workers;
- Training records.

5.0 Safety Requirements for X-ray Use

The primary hazard of analytical XED's is the ionizing radiation produced and the potential for biological damage as a result of exposure to X-rays. Therefore, most of the safety requirements that are implemented are related to preventing exposure to X-ray radiation. There are two types of safety requirements associated with this type of equipment:

- design safety requirements;
- administrative control measures.

5.1 Design Safety Requirements

The design safety requirements for analytical X-ray equipment are specified in the Radiation Emitting Devices Regulations and Health Canada's Safety Code 32. Table 1 identifies the design safety requirements for all existing X-ray diffraction (XRD), X-ray fluorescence spectrophotometer (XRF) and cabinet X-ray equipment.

Table 1: Design Safety Requirements – all analytical X-ray equipment

Item	Engineering Control	XRD	XRF	Cabinet
1.	A label exists on the control panel with the X-ray	Х	Х	Х
	warning symbol in two contrasting colors and the			
	words:			
	"CAUTION — X-RADIATION. This Equipment Produces High			
	Intensity X-radiation When energized. To be Operated			
	Only by Qualified Personnel. ATTENTION — RAYONNEMENTS Y Cet appareil produit			
	des rayonnements X haute intensité lorsqu'il est sous tension.			
	Son utilisation est réservée au personnel compétent."			
2.	A label exists on the control panel and the external	Х	Х	Х
	surface of any enclosure door or access panel with			
	the X-ray warning symbol and the words:			
	"CAUTION: X-RADIATION – ATTENTION:			
	RAYONNEMENTS X"			
3.	Controls, meters, lights and other indicators are	Х	Х	Х
	readily discernable and clearly labelled as to			
	function.			
4.	There are separate fail-safe lights to indicate when	Х	Х	Х
	the X-ray tube is energized and when X-rays are			
	being produced.			
5.	Warning lights exist to indicate the open/shut status	Х	Х	n/a
	of radiation aperture shutters.	,		
6.	A beam limiting device exists for cabinet X-ray	n/a	n/a	Х
	equipment to align the beam with the detector.			
/.	A control panel exists that regulates the X-ray tube.	X	X	X
8.	A power ON/OFF switch must be installed to	Х	Х	Х
0	energize the equipment.			
9.	An A-ray ON/OFF switch must be installed.	X	X	X
10.	A Reviock control switch of an alternate device must	Х	Х	Х
	removed			
11	Warning indicators must be installed to indicate the	v	v	n/a
11.	open/shut status of shutters	Λ	Λ	11/ a
12	Radiation aperture shutters remain closed when not	x	x	n/a
12.	in use. Positive operator action is required to open a			n, u
	radiation aperture shutter.			
13.	Radiation aperture shutters are equipped with an	Х	Х	n/a
	interlock in the operating mechanism.			
14.	X-ray tubes not in use are either disconnected or	Х	Х	n/a
	removed.			
15.	Unused beam ports are permanently blocked-off with	X	Х	n/a
	lead.			
16.	Unused shutters are secured to prevent casual	Х	X	n/a
	opening.			
17.	For equipment operating under an open beam	X	X	Х
	configuration access to the radiation field must be			

	restricted by some means such as a physical			
	enclosure.			
18.	Enclosures surrounding equipment with open beams	Х	Х	Х
	have sliding doors or similar access openings.			
19.	Enclosures surrounding equipment with open beams	Х	Х	Х
	have an automatic shut-off or audible alarm when			
	any sliding door or access opening is not in the			
	closed positions.			
20.	An enclosure surrounding equipment with open	Х	Х	Х
	beams attenuates the radiation level to $< 4.39 \ \mu$ Sv/hr			
	or less at 5 cm from its external surface.			
21.	A warning sign of the type described in Item 1 that is	Х	Х	Х
	clearly visible at any time on a part of the sliding			
	door or similar access opening.			
22.	Fail-safe interlocks should be installed on accessories	Х	Х	Х
	or components for which their removal would cause			
	direct access to the primary beam or to high radiation			
	areas on the equipment.			

In addition to the requirements specified in Table 1 which are applicable to all X-ray equipment, any X-ray equipment which was manufactured <u>after 1981</u> when the Radiation Emitting Devices Regulations came into effect must also comply with the requirements specified in Table 2.

Item	Engineering Control	XRD	XRF	Cabinet
1.	The make, model, serial number, date and country	Х	Х	Х
	are indicated on the control panel and accessories.			
2.	Where a radiation aperture must be opened in order	Х	Х	Х
	to set up or align the equipment, a visual and audible			
	indicator warns the operator that the radiation			
	aperture is open for the duration that it is open.			
3.	Indicators and meters of tube voltage and current	Х	Х	Х
	exist for each X-ray tube.			
4.	A timing device exists for each X-ray tube.	Х	Х	n/a
5.	The radiation beam is contained within protective	Х	Х	Х
	shielding that is equipped with an interlock.			
6.	Radiation aperture shutters can be removed only with	Х	Х	n/a
	special tools.			
7.	Radiation aperture shutters are designed with	Х	Х	n/a
	protective shielding.			
8.	There are labyrinth-type joints, couplings or	Х	Х	n/a
	interfaces between radiation apertures, shutters,			
	protective shielding, beam limiting devices and			
	accessories.			
9.	Interchangeable filters have interlocks or other	Х	Х	n/a
	means to ensure that insertion or removal of those			
	filters is possible only when X-rays are not being			
	produced.			

Table 2: Design Safety Requirements –equipment manufactured after 1981

10.	Interchangeable filters have filter slots that are covered by protective shielding when they are not in use.	Х	X	n/a
11.	Accessories supplied by the manufacturer contain information that sets out the specific analytical X-ray equipment for which the accessory is designed.	Х	Х	n/a
12.	Accessories supplied by the manufacturer have information that indicates the design and specification of couplings, fittings, interfaces and parts necessary for the installation and functioning of that accessory.	Х	Х	n/a
13.	Accessories associated with the production, collimation, transmission or detection of X-rays shall be contained within protective shielding that prevents the radiation beam from touching any part of the operator's body.	Х	Х	n/a
14.	Accessories associated with the production, collimation, transmission or detection of X-rays shall be equipped with an interlock.	х	x	n/a
15.	Radiation does not exceed ~4.3 μ Sv/hr at a distance of 5 cm from any accessible external surface of any X-ray tube housing, beam-limiting device, protective shielding or accessory. (For cabinet X-ray equipment this may be averaged over 10 cm ²).	X	X	X
16.	X-radiation does not exceed $\sim 4.3 \mu$ Sv/hr at a distance of 5 cm from any radiation aperture, shutter or filter slot that is in the closed position.	Х	X	n/a
17.	X-radiation does not exceed ~ 4.3μ Sv/hr at a distance of 5 cm from any point on the housing of the high- voltage generator.	Х	x	n/a
18.	Instructions from the manufacturer as to the installation, interconnection, testing, operation and maintenance of the equipment and its accessories or replacement components are available.	X	Х	X
19.	Information from the manufacturer on the recommended accessories and replacement components is available.	X	Х	n/a

Table 1 and 2 modified from Table 1 and 2 of the University of Alberta X-ray Safety manual.

5.2 Administrative Safety Requirements

In addition to design safety features, administrative control measures (operational and maintenance) are important for establishing a safe work environment around XED's. For equipment manufactured prior to the establishment of the Radiation Emitting Devices Regulations (1981) some of the design safety features that are found in newer equipment may not exist and it is imperative in that case that administrative control measures be implemented to establish an equivalent level of safety with the older equipment.

In general, the three ways that radiation exposure can be reduced include; minimizing the exposure <u>time</u>, increasing the exposure <u>distance</u>, and the use of <u>shielding</u>. The following paragraphs provide some specific information on how these principles can be applied in the use of analytical X-ray equipment.

5.2.1 General safeguards

In order to achieve an acceptable level of protection, X-ray facilities must include the following safeguards:

- Allocate a room, or portion thereof, in order to isolate the X-ray emitting device. The entrance to the room must display an approved sign indicating the presence of XED's (see Section 4.5)
- Access to the room housing the XED must be restricted to authorized X-ray workers whenever the X-ray equipment is in use.
- For operations not requiring constant user supervision or surveillance, the analytical equipment must be adequately secured (i.e. within a locked room) to prevent access by unauthorized individuals.
- Personnel must not expose any part of the body to the primary beam. If and when alignment of analysis accessories requires the use of an open X-ray beam, specific precautions must be exercised to reduce or eliminate radiation exposures to the extremities and other parts of the body. Long-handle forceps or remote handling devices, low X-ray tube current and fluorescent beam-definers of higher radiation sensitivity should be employed.
- While it may be necessary under some circumstances for maintenance operations to be performed with stray radiation fields above the regulatory limit (~4.3 μ Sv/hr), every effort must be made to minimize exposures to organs or parts of the body that could be affected. The maximum permissible dose limits must not be exceeded by any maintenance personnel and in general the radiation exposure should be kept as low as reasonably achievable (ALARA).
- All protective apparel and safeguards, including the radiation survey meter(s), must be tested regularly to ensure that they are in proper working and functional condition and are not defective. Proper documentation that such tests were carried out should be maintained.

5.2.2 Pre-operational Safety Checks

Pre-operational safety checks shall be carried out after installing XED's or accessory components and after conducting maintenance on the equipment. The safety checks should ensure:

- the proper functioning of all protective and safety devices;
- the proper assembly and functioning of all radiation shields, beam ports, accessories and fittings;
- that ambient radiation levels are within the permissible regulatory limit (~4.3 μ Sv/hr at 5 cm from all external surfaces of the equipment) by using an appropriate survey meter;
- that any safety by-pass procedures are of the one-time actuation type and revert back to a failsafe situation at start-up time of the X-ray generator.

5.2.3 Maintenance Safeguards

The greatest risk of radiation exposure from analytical X-ray equipment occurs during maintenance procedures in which personnel are potentially exposed to the primary beam or intense scatter radiation. Therefore, it is imperative that manufacturer's guidelines be followed and that unauthorized individuals are not near the XED. The following procedures must be followed during maintenance of the XED's:

• Test all safety devices and features and ensure their proper functioning. If by-passing a safety device is deemed essential to facilitate a specific maintenance task perform the following:

- install a flashing red light or intermittent sound signal that is clearly visible or audible to a person with normal or corrected vision and hearing within the room housing the equipment where the safety device was altered;
- attach, near the flashing red light or intermittent sound signal, a written notice that indicates explicitly what safety device was altered;
- use an appropriate survey meter if radiation emissions are potentially associated with the intended task, and ensure that the permissible limits are not exceeded.
- ensure that the safety device is re-established and that any shielding that was removed or modified to facilitate the intended task is replaced after the task is completed.
- Examine all radiation shields, beam ports, shutters, accessories and fittings for proper installation and function;
- Monitor the radiation levels nearest that part of the equipment where maintenance functions will be carried out, before and after the maintenance functions(s). Use an appropriate survey meter and observe the guidance reference limits for body organs and the permissible levels established for the performance of the equipment.

5.2.4 Radiation Protection Surveys

Radiation protection surveys of analytical XED's are intended to determine whether the equipment functions according to applicable design and performance standards and are used and maintained in a way that provides maximum radiation safety to all persons. In order to achieve these objectives, the following requirements apply to all facilities:

- Analytical X-ray emitting devices must be surveyed when initially installed, and when maintenance, modifications, damage or overexposure accidents have occurred.
- Surveys must be performed by a Service NL inspector (or authorized equivalent) <u>biennially</u> as part of the process for registering the equipment.
- Routine surveys of X-ray equipment should be conducted at a frequency that depends on the particular equipment design, conditions of use, and performance history. The survey frequency may be based on consultation with the RSO.
- Surveys of analytical X-ray emitting devices must include:
 - a thorough inspection of all safety devices and radiation shields;
 - stray/scattered radiation measurements carried out under worst-case (if feasible) user conditions around the system;
 - proper quantification of stray radiation levels above the regulatory limit and their exact distance specification of the area or location on the X-ray emitting device where they were found;
 - an assessment of occupational and public exposures when radiation levels have exceeded the regulatory limit;
 - room shielding integrity;
 - audits on:
 - the availability of a copy of Health Canada's Safety code 32, applicable radiation safety rules, safe operating and emergency procedures at or near the analytical X-ray emitting device,
 - the maintenance program established and followed by the equipment owner or designee,
 - reports of unsafe operational conditions, overexposure incidents and accidents;

- o review and assessment of personal dosimetry records.
- Survey reports must state the following:
 - an identification of the X-ray emitting device that sets out the manufacturer, brand name, model number, serial number, and the date of manufacturer;
 - an assessment of the safety devices, radiation shields, occupational exposures, and personal dosimetry records and the deficiencies observed;
 - specific corrective actions necessary for compliance with this manual, Health Canada's Safety Code 32, and the Radiation Emitting Devices Regulations, including completion deadlines;
 - safety recommendations (if any);
- After an X-ray emitting device has been decommissioned, all survey reports pertaining to that equipment shall be forwarded to the RSO for retention.

6.0 Glossary

ALARA

Acronym for As Low As Reasonably Achievable. This is a philosophy that pertains to keeping the dose rates received by personnel as low as possible taking into account the regulatory dose limits, social and economic factors being taken into consideration.

Absorbed Dose

The quantity of radiation energy absorbed per unit of mass of material. The SI unit for absorbed dose is the Gray (Gy) (Old unit: rad. 1Gy = 100 rad).

Air Kerma

The sum of the initial kinetic energies per unit mass of all the charged particles liberated by uncharged ionizing radiation in air.

Background Radiation

Radiation from non-occupational sources. This includes medical device exposures, cosmic and terrestrial radiation, and radiation consumer products).

Bremsstrahlung Radiation - German for "braking radiation".

The effect of slowing, changing direction or accelerating an electron (or any other charged particle) moving in the strong electric nucleus field of an atom; results in the decreasing of the kinetic energy of the incoming charged particle to varying degrees. In this process the electrons give up their energy in the form of X-rays. This process of X-ray production is also called bremsstrahlung.

Characteristic X-rays

X-rays can be created when electrons undergo a change in the amount of energy they possess. When a vacancy is created in the inner orbital shell of an atom, the electrons from the higher energy outer shell drop to fill the inner vacancy. The atom decreases the amount of energy it possesses, the lost energy are the X-rays given off by the atom. The emission of X-rays is "characteristic" (like a signature or fingerprint for that atom) of the target atom and whose energy corresponds to the difference between the initial and final electron energy state.

Collimator

Is a device or mechanism that limits the shape and size of the useful beam.

Dose Rate

The amount of radiation received in a given period of time. Example; milliSievert per hour (mSv/h).

Dosimeter

Personal dosimeters are worn by a worker and record total dose received from occupational exposures to ionizing radiation (including X-ray producing machines).

Electron Volt (eV)

The unit of energy defined as; the amount of energy required to accelerate one electron through an electron potential of one volt. The energy for X-rays is greater than 5 keV but typically range from 40-100 keV (keV = thousands of electron volts).

Equivalent Dose

A measurement of the biological effects on a specific tissue or organ exposed to each individual radiation type. It is a function of the absorbed dose and is dependent on the type of radiation absorbed, with each type of radiation is assigned a weighting factor. The radiation-weighting factor for X-ray is 1. The SI unit for effective dose is the Sievert. (Sv) (Old unit: roentgen equivalent man [rem] 1 Sv = 100 rem).

Effective Dose

A measurement of the whole body dose based on the summation of the equivalent dose received by all organs. In order to calculate this, a tissue weighting factor is applied to gauge the contribution by each organ. The SI unit for effective dose is the Sievert (Sv).

Exposure

A measure of X-ray intensity in terms of its ionizing effect in air. The SI unit for exposure is coulombs/kilogram (C/kg) (Old unit: roentgen [R] 1 C/kg = 3876 R).

Failsafe Design

A design feature of an X-ray device whereby any failure of a device safety system or sub-assembly causes the device to stop production or emission of X-rays.

Filtration

The use of metal filters to "harden" the X-ray beams from low, medium and high energy X-ray emitting devices to give the X-rays the ability to penetrate the target further.

Genetic Effects

Biological effects from ionizing radiation exposure that are passed from parent to child at the time of conception.

Gray

Unit of absorbed dose in SI = Gray (Gy).

Ionizing Radiation

A source of energy (radiation) which has sufficient energy to physically knock electrons from an atom resulting in the creation of ion pairs. Threshold energy for ionization = 34 eV

Principal Investigator

A Memorial University of Newfoundland faculty member who is in charge of an X-ray source situated on any campus of Memorial University of Newfoundland.

Photoelectric Effect

One method of ionization from gamma radiation where an incident photon (X-ray or gamma ray) interacts with one orbital electron. The photon transfers all of its energy to the electron at which point the photon no longer

exists and causes the electron to be ejected from its orbit. This ejected electron can then cause secondary ionization and in the process reduces its energy. The photoelectric effect occurs mainly with low energy gamma photons (< 0.5 MeV).

Radiation weighting factor - Quality factor

A numerical value (or "weight") given to the different types of radiation which takes into account the effect of each type of radiation on human body (Ex. 1 for beta, gamma and X-rays up to 20 for alpha particles and high-energy neutrons).

Redundant

When used in reference to X-ray radiation safety systems, means a safety system having two or more separate and equivalent units designed so that the failure of one unit will not affect the operation of other unit(s).

Scattered Radiation - Compton scattering.

One method of ionization from gamma radiation where a photon interacts with an electron in orbit and only some of the energy of the photon is transferred to the electron. The result is that the electron is ejected from orbit and the original photon (which now has less energy than originally) is scattered in a different direction. The scattered photon may undergo other scattering processes, resulting in further loss of energy. The probability of scattering (Compton Effect) is highest with photons of medium energy (~ 0.5 MeV - 3 MeV).

Seivert

SI unit for both equivalent and effective doses (Sv).

Shielding

Radiation absorbing material (usually lead) used to attenuate the absorbed dose or absorbed dose rate imparted to tissue from X-rays.

Sky shine

X-rays that scatter over and around the shielding.

Somatic Effects

Biological effects from ionizing radiation exposure, that are manifest in the organisms' lifetime. Somatic effects can result from acute or chronic doses of X-ray radiation.

Tissue Weighing Factor

A numerical value (or "weight") applied to tissues to account for the biological effect of radiation on different organs or tissues in the human body. The tissue weighting factor is used to calculate the effective dose where equivalent doses received by human organs are known.

X-ray emitting device (X-ray machine)

A device powered by electrical current used to generate an X-ray beam by sending electrons into a target. The X-ray emitting device is an analytical device used primarily to analyze the structure of materials.

X-ray source

The part of the X-ray emitting device that emits X-rays.

X-ray worker

Any Memorial University of Newfoundland employee/student who in the course of their work/studies is likely to receive a dose of ionizing radiation in excess of the annual dose allowed to the general public (1 mSv). The

minimum age of a person allowed to operate or receive a dose of X-ray radiation from an X-ray emitting device is 16 years.

X-ray emitting device supervisor

An X-ray worker who is designated by the Principal Investigator to supervise the safe use of an X-ray emitting device. The X-ray supervisor will have advanced knowledge, experience, and training in the use of the X-ray equipment and safety practices.

X-ray

An X-ray is a type of ionizing radiation (maximum energy greater than 5 KeV) that is produced from X-ray emitting machines. X-ray made up of individual packets of energy called photons (as opposed to alpha, beta radiation and neutrons which are composed of particles).

7.0 Resources

Health Canada Requirements and Guidance for Analytical X-Ray Equipment, Safety Code 32: <u>http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/94ehd-dhm186/index-eng.php</u>

Addendum to Safety Code 32: Portable, hand-held, X-ray tube based open-beam XRF devices: <u>http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/safety-code_32-securite/index-eng.php</u>

Health Canada Safety Procedures for the Installation, Use and Control of X-ray Equipment in Large Medical Radiological Facilities, Safety Code 35: <u>http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/safety-code_35-securite/index-eng.php</u>

Radiation Emitting Devices Act: <u>http://laws-lois.justice.gc.ca/eng/acts/R-1/index.html</u>

Radiation Emitting Devices Regulations: http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._1370/

Radiation Health and Safety Act, Government of NL: <u>http://www.assembly.nl.ca/legislation/sr/statutes/r01.htm</u>

Radiation Health and Safety Regulations, Government of NL: http://www.assembly.nl.ca/Legislation/sr/Regulations/rc961154.htm

Special thanks go to the University of Victoria and University of Alberta for use of their X-ray Safety Program Manuals.

Appendix 1: In-house training log (click on icon to hyperlink to document).

		March 2016				
XED Respor	XED Responsible User:					
XED Registr	XED Registration #:					
Authorized v	vorker name:					
Authorized v	vorker job title:					
Date	Trainer	Procedure/protocol/equipment				
		MUN X-ray Safety Manual reading*				
AN A C	the second se	In the Advertised Street Manual				

X-ray Safety Training Log

X-ray Safety Training Log, XTL v1	Responsible Committee: University Radiation Safety Committee	Page 1 of 1
Date of first issue: n/a	Date of last review: March 2016	Date of next review: 2019

e latest version of this document please go to: h

Appendix 2: X-ray worker registration form (click on icon to hyperlink to document).



X-ray Worker Registration Form

Please complete all applicable sections of this form if you will be working in a laboratory where X-ray emitting devices (XED) are in use.

Worker Name (Surname) (Surname)	Male Female
Position If other, describe	
Email My.mun.ca login name	
Office # Office telephone #	
XED Responsible User (listed on certificate of registration)	
Faculty/department/division	
Radiation dosimetry registration	
Date of birth Social Insurance Number (SIN)	
Place of birth (Province of Canada or country if outside Canada)	
Have you worn a radiation dosimeter badge before?	
If yes, when and where?	
XED equipment information	
XED type Uses per month	
Service NL XED Registration #	
X-ray Worker Registration, URCC-7 v2 Date of first issue: June 2016 Responsible Committee: University Radiation Safety Committee Date of last review: June 2016 For the latest version of this document please go to: http://www.mun.ca/heath_safety/OHSMB/XSM8/	Page 1 of 3 Date of next review: 2019 07/06//2016

Responsible Committee: University Radiation Safety Committee Date of last review: Sept 2016

Appendix 3: X-Ray Equipment Safety Inspection Checklist (click on icon to hyperlink to document).

Notes

- 1. Responsible users must use this form when conducting **annual** internal safety inspections.
- 2. Completed X-ray safety inspection checklists should be submitted no later than June 30 of each year.
- 3. Permit holders must keep a record of all safety inspections indefinitely.

MEMORIAL UNIVERSITY Department of Health and Safrey	X-ray Safety I	nspection Checklist
Date of Inspection:		Inspector:
Permit Holder:		Permit Number:
Room Number:		Permit Expiration Date:
XED Make/ Model:		XED Registration #:
Inspection History:		
Deficiencies discovered last inspection ((provide inspection date)	Status of Deficiency Correction (corrected, not corrected, other)

The following inspection checklist is based on the requirements of the Health Canada Safety Code 32: Safety Requirements and Guidance for Analytical X-ray Equipment, and the NL Radiation Health and Safety Regulations.

1