Radiation Safety Training for Intending Users of Hand-held X-Ray Fluorescence Analysers Industrial Radiation Safety Level 2 Course

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These notes have been developed for persons seeking a Licence to Use Analytical X-Ray unit (hand-held) for Chemical Analysis

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ARPANSA Web based information
International Commission on Radiological Protection Web based information

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Why is this course needed?

In Queensland, Radiation Health administers Queensland's *Radiation Safety Act 1999* and the Radiation Safety Regulation 2021.

To obtain a Use Licence Issued by Radiation Health Qld, you are required to complete an approved training course that specifically addresses:

- The Hazards associated with use of HHXRF.
- How to address the hazards.
- Safe Working Rules.
- Remediation Procedures.
- Obligations under the Radiation Safety Act 1999.
    - The objective of the Radiation Safety Act 1999 is to protect persons and the environment from the health risks associated with exposure to sources of ionising radiation and harmful non-ionising radiation.

In order to obtain a Use License, you need to demonstrate that you understand how to use the HHXRF in a safe manner to ensure that all doses to persons are kept within the prescribed limits and are:

As **L**ow **A**s **R**easonably **A**chievable

This can be achieved from

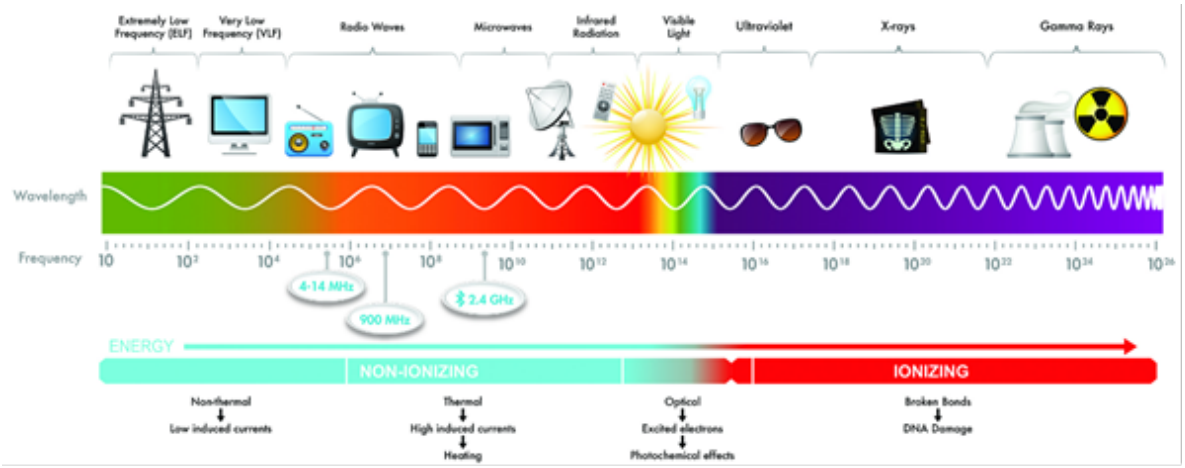
- Successfully completing an approved course
- Undertaking site work under supervision
- Submitting an application and paying prescribed fees.

What is X Ray Fluorescence (XRF)?

X-ray fluorescence or XRF is an analytical technique that has been used for many years to determine the elemental composition of a wide variety of materials.
Examples include metal alloys, minerals, and petroleum products.
X-rays form part of the electromagnetic spectrum. They are on the high-energy side of ultraviolet and are expressed in terms of their energy in kilo electron volts or wavelength in nanometres.
XRF can typically analyse elements from sodium to uranium in concentrations ranging from parts per million to high percent's, in solids, liquids, and powders.

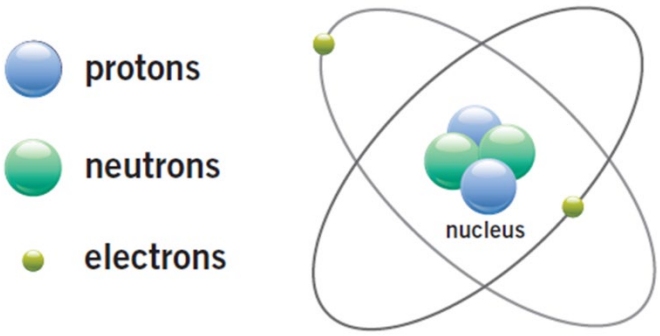
What is Radiation?

Figure 1 - The Electromagnetic Spectrum



Ionisation is the removal of electrons from atoms when radiation interacts with material.
Non-ionising radiation is radiation that does not have enough energy to knock electrons from orbit of the atoms that it hits. This is the category of radiation that radio waves, microwaves, infrared and visible light belong to.
To understand radiation, it is important to know what an atom is.
Atoms are tiny particles that all matter is made of.
They are made of smaller particles called protons, neutrons, and electrons.
Protons have a positive charge; electrons have a negative charge and neutrons have no charge.
The centre of the atom is called the nucleus.

Figure 2 – Basic Helium Atom



Radiation is either subatomic particles or electromagnetic waves which are emitted by an unstable atom or when electrons lose energy.
Electromagnetic waves are pure energy with no mass.
Particles that come from an atom are: protons, neutrons and electrons.
Since radiation is made up of particles which are smaller than atoms, or waves which have no mass, it can travel through solid objects.

What is a Radiation Source?

A source can either be a radioisotope or a radiation apparatus, e.g. Xray machine.
An isotope source is a small capsule that contains radioactive material and emits radiation.
The Nitons, Xmets, Hitachis and Delta Pros are all radiation apparatus and DO NOT use an Isotope source.

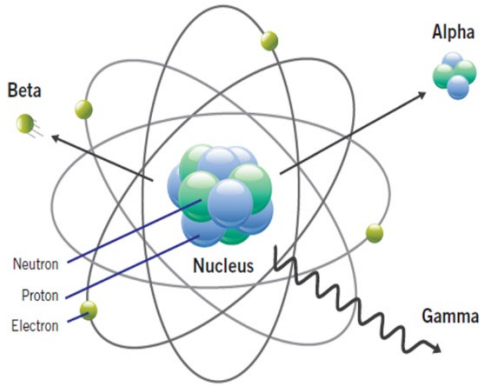
Types of Radiation

Radioisotopes

The common types of ionizing radiation are alpha and beta particles, gamma rays, and x-rays.

An alpha particle is a grouping of 2 protons and 2 neutrons emitted from an atom.
A beta particle is an energetic electron emitted from an atom.
Gamma Rays and X-Rays are waves of electromagnetic energy emitted from an atom.

Figure 3 – Radiation Particles and Energy Emissions

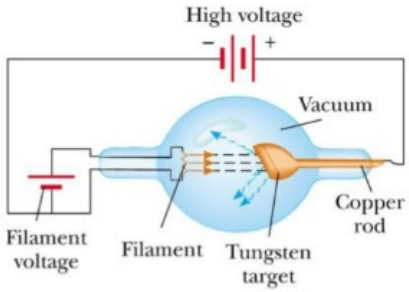


- Alpha Particles
- Beta Particles
- Gamma rays
- X-rays
- Neutrons

X Rays

X-Rays are high energy electromagnetic waves moving through space.
X-Rays are emitted when an electron loses energy. This occurs in the electron shells of an atom and do not come from the nucleus of the atom.
They are produced through specific interactions between electrons and atoms.
Like gamma rays, x-rays are very penetrating. We can use materials, like lead, to reduce the number of x-rays that will reach our bodies.

Figure 4 - X Ray Tube



X-ray devices are not radioactive as such. The handheld XRF Analysers used are designed to produce radiation that is controlled by the operator.

The radiation can be turned on and off by the press of a button. Electricity is used to supply energy to the device so that the x-rays can be created.

Without electricity, there would be no way for an x-ray device to actually emit x-rays.

X-rays are created by creating a potential difference between the Anode and Cathode in the vacuum tube which essentially is like “firing” electrons at a target material.

The energy of the Xray’s emitted depends on the Kilovoltage peak (kVp) it determines the highest energy of x rays and is responsible for the acceleration of electrons from the cathode to the anode and the milliampere-seconds (mAs) which is a measure of radiation produced over a set amount of time. An increase in current (mA) results in a higher production of electrons that are inside the Xray tube which will therefore increase the quantity of radiation.

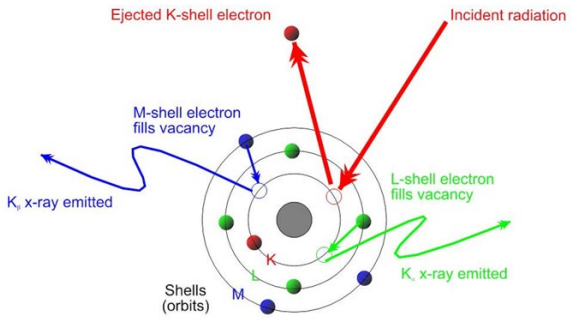
Of the number of electrons that hit the target anode, only 1% are generated as X-Rays with the remaining being converted to heat.

How does XRF Work ?

All XRF instruments are designed around two major components:
An X-ray source, commonly an X-ray tube
Detector.
Primary X-rays are generated by the source and directed at the sample's surface, sometimes passing through a filter to modify the X-ray beam. When the beam hits the atoms in the sample, they react by generating secondary X-rays in the sample that are collected and processed by a detector.

Electrons are fixed at specific energies in their positions in an atom, and this determines their orbits. Additionally, the spacing between the orbital shells of an atom is unique to the atoms of each element, so an atom of potassium (K) has different spacing between its electron shells than an atom of gold (Au), or silver (Ag), etc.
When electrons are knocked out of their orbit, they leave behind vacancies, making the atom unstable. The atom must immediately correct the instability by filling the vacancies that the displaced electrons left behind. Those vacancies can be filled from higher orbits that move down to a lower orbit where a vacancy exits.
For example, if an electron is displaced from the innermost shell of the atom (the one closest to the nucleus), an electron from the next shell up can move down to fill the vacancy. **This is fluorescence**.

Figure 5 – XRF Principal



Measuring Radiation Dose

The probability of a harmful effect from radiation exposure depends on what part or parts of the body are exposed.
We measure the radiation we receive in terms of "exposure". Exposure measures the effect of radiation on substances that absorb it.
Radiation exposure is expressed in several ways to account for the different levels of harm caused by different forms of radiation and the different sensitivity of body tissues.
An equivalent dose is the effect of radiation exposure on human tissue. This relates the absorbed dose in human tissue to the effective biological damage of the radiation.

Different radiations have their own weighing factors,
W_R for X and γ rays and electrons = 1
W_R for alpha particles = 20
Not all radiation has the same biological effect, even for the same amount of absorbed dose.
Equivalent dose is measured in an international (SI) unit called the Sievert (Sv).
The Sievert is a large unit and for normal radiation protection levels a series of prefixes are used:
micro-Sievert (µSv) is one millionth of a Sievert (1/1,000,000)
milli-Sievert (mSv) is one thousandth of a Sievert (1/1,000)

Effective Dose

The probability of a harmful effect from radiation exposure depends on what part or parts of the body are exposed. Some organs are more sensitive to radiation than others.
A tissue weighting factor is used to take this into account. When an equivalent dose to an organ is multiplied by the tissue weighting factor for that organ the result is the effective dose to that organ. The unit of effective dose is the sievert (Sv).
In an industrial setting a Whole-body dose rate of 1 is applied and the extremities is 0.01.
This means that the hands and feet aren't as sensitive as the organs in the trunk of the body where rapid cell division occurs.

Under normal safe operating conditions, a total effective dose from using a HHXRF contributes no more than background radiation. When ever any radiation source is used, the goal should be to keep the maximum exposure As Low As Reasonably Achievable.

Exposure to Ionising Radiation

Background radiation

Natural background radiation is the ionising radiation that we, and other living organisms, are exposed to every day.

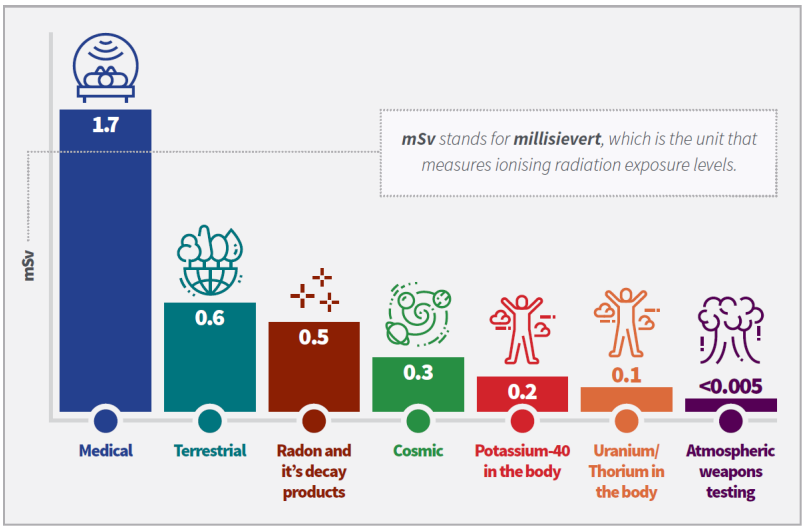
The largest contributing source of radiation exposure comes from external exposure to natural radioactivity in rocks, soil, building materials (terrestrial radiation) and inhalation of radon gas that exhales from the ground or building basements.

There are also contributions from cosmic radiation depending on where you live, and naturally occurring radioactivity in food and in the body.

In Australia, medical exposure is the largest contributor by far, with only negligible contributions from industrial radiation sources.

Average background radiation in Australia is 2000µSv/year (2mSv). This equates to around 0.75 to 1.0µSv.h^{-1}.

Figure 6 – Sources of Background Radiation



(courtesy ARPANSA)

Some places are known to have considerably higher background levels. For example, some granites contain large amounts of K-40 as potassium feldspar, and higher levels of minerals like monazite, which contain thorium, background levels are elevated. Castle Hill in Townsville, for example, has a background of up to 4 mSv/year, while parts of Cornwall, England have even higher dose rates. Considerable areas of Kerala State in India, for example, have a background level of up to 13 mSv/year. It is important to note that these areas do not report significantly higher levels of genetic abnormalities or cancer.

In other areas, uranium and its daughter radium may be higher than average. Again, higher background levels in such areas do not seem to cause health problems, although care must be taken that accumulations of the **gas radon** don't occur.

Planned Exposures

To put these dose limits into context; for an occupationally employed radiation worker (OERW) who is monitored, an annual dose rate of 20mSv/year is permitted however a once of dose limit 50mSv/year provided the remaining 5-year average does not exceed 100mSv. Higher limits apply to parts of the body,

for example the extremities (hands & legs) have a dose limit of 500 mSv - this is because there are no rapidly dividing cells in the extremities.
For a member of the public an annual dose rate of 1mSv/year is permitted. Once an OERW declares her pregnancy, a maximum of 1mSv to the foetus for the remainder of her pregnancy shall apply.

Table 1 – Occupational Dose Limits (18 years and over)

Type of limit	Limit (18 years and over)[1]
Effective dose	20 mSv per year, averaged over a period of five consecutive years *(Can be exceeded to 50 mSv in a single year however 5 year average must not exceed 100 mSv)*
Annual equivalent dose to the lens of the eye	20 mSv per year, averaged over a period of five consecutive years *(Can be exceeded to 50 mSv in a single year however 5 year average must not exceed 100 mSv)*
Annual equivalent dose to the skin[4]	500 mSv per year
Annual equivalent dose to the hands and feet	500 mSv per year

Damaging levels of Radiation

In terms of the dose units defined above, 1 Sievert, or 1000 mSv, is a moderate dose level for a single whole-body dose which will cause symptoms of radiation sickness to appear in most Individuals. These tissue reaction symptoms are related to damage to rapidly dividing cells in the digestive system and are typically nausea and diarrhea. Fatigue may also occur due to damage to red blood cells, while damage to the white cells and platelets can cause immune deficiency, and internal bleeding. The severity of these symptoms increases with the dose level, until at doses of 5 to 8 Sieverts, all exposed individuals will die of radiation sickness in the following four weeks, even with specialized treatment. (If the dose is localized to a particular area of the body, only that area will be damaged. This is the basis for the treatment of inoperable cancers, such as brain tumors, or in post-operative treatment of malignant cancers.)

Low doses of less than 100 mSv do not cause immediate harm, but there are some cumulative effects that are of concern if such doses are repeated. Unlike radiation sickness, however, these effects are "random" in the sense that some individuals will exhibit a serious side effect such as genetic damage or cancer, while others exposed to similar doses will not. This is because the crucial damage occurs to the genetic material, or the DNA. In a single human cell, it is then a matter of chance whether this cell proliferates, and the damage is expressed in tangible ways. Or the cell may die or be attacked successfully by a healthy immune system. Despite the random nature of the causes of chronic, low-level doses of radiation, realistic estimates can be made of the effects. For cancer of all types, the risk of a fatal cancer being induced by cumulative doses of Ionising radiation totaling 1000 mSv is thought to be 4.5%. At the radiation worker limit of 20 mSv, the risk is thought to be proportionally less and becomes just under 0.1% that a fatal cancer was caused by a radiation dose. Expressed another way, this is around 1 in 1,000 and is obviously "small but finite". This is a good reason for the radiation dose limits to be treated

as absolutes. (In radiation protection terms, this equates to the ALARA Principle: all doses should be kept "As Low As Reasonably Achievable".)

At the 1 mSv general public dose limit, the risk extrapolates to 0.005%, or about 1 in 20,000, if the "Linear No Threshold" model is used. It is good common sense that doses at (or below) background should not be a cause of cancer. After all, humans are the most successful mammals, and if our DNA were susceptible to damage from background levels of Ionising radiation, "we" would not be here today. It has been suggested that this is simply because DNA that was susceptible to radiation damage at background levels has not survived for long enough to successfully reproduce.

Genetic damage is another possible outcome of radiation damage to cellular DNA in the human reproductive cells. These cells are by their nature particularly sensitive to radiation damage at the time of conception, and in the first few months of the fetus' life. The observed "normal" spontaneous rate of birth defects of all types in humans is ~0.8%, and it is estimated that this rate might be doubled by a radiation dose of about 500 mSv to one of the parents. (This "doubling dose" comes from experiments on mice and animals with similar DNA to humans, however it has not been able to be confirmed in humans.) Extrapolating to a 20 mSv dose and expressing the result as an increase in this risk, a radiation worker may face an increased risk of 1 in 25 or a birth defect. To put this as plainly as possible, the risk might increase from 0.8% of a natural birth defect, to 0.83% of natural + radiation-induced birth defect, following an exposure to a single dose of 20 mSv. Of considerable concern is that genetic damage is essentially permanent, and that the genetic damage may not be expressed until later generations. (The United Nations expresses this as a risk of 0.3% per Sv of "severe genetic harm" in the first generation, and 1.2% per Sv for all generations. These are "worst case" figures - there is no firm evidence for viable human mutations, but the UN is understandingly being conservative.)

To put the estimation of risks of low doses into some perspective, the following statement from the US Health Physics Society should be borne in mind, as it contradicts the risk estimates made using the "Linear No Threshold" model as described above.

"*Radiogenic Health Effects Have Not Been Observed Below 100 mSv":*

Radiogenic health effects (primarily cancer) are observed in humans only at doses in excess of 100 mSv delivered at high dose rates. Below this dose, estimation of adverse health effects is speculative. Risk estimates that are used to predict health effects in exposed individuals or populations are based on epidemiological studies of well-defined populations (e.g. the Japanese survivors of the atomic bombings in 1945 and medical patients.) exposed to relatively high doses delivered at high dose rates. Epidemiological studies have not demonstrated adverse health effects in individuals exposed to small doses (less than 100 mSv) delivered in a period of many years."

Table 2 – Short Term Effects of Acute Radiation Exposure

Short term effects of acute radiation exposure

from the US Centre for Disease Controls Emergency Response site:
http://www.bt.cdc.gov/radiation/arsphysicianfactsheet.asn

Dose (Sievert)	Effects (Note: LD 10/30 means 10% mortality in General Public after 30 days)
0.05 - 0.2	None felt; low risk of cancer & genetic damage.
0.20 - 0.50	None felt; red cell count decreases temporarily.
0.50 - 1.00	Mild; headache, increased risk of infection, temporary male sterility (TMS) possible.
1.00 - 2.00	Mild; **LD 10/30**, moderate nausea, vomiting 3 - 24 hrs, then latency in felt effects 10 -14 days, then illness/fatigue, immune system depressed, TMS, stillbirths/ miscarriages.
2.00 - 3.00	Moderate; **LD 35/30**, Nausea, vomiting, hair loss, fatigue, massive loss of white cells, males permanently sterilised & females possible. Convalescence 1 - several months.
3.00 - 4.00	Severe; **LD 50/30**, increased symptoms as above + uncontrollable bleeding in mouth, skin & kidneys.
4.00 - 6.00	Acute; **LD 60/30** (90% at 6 Sv) death primarily from infection I internal bleeding; convalescence several months to a year.
6.00 - 10.00	LD **100/14**; survival only with intense medical care & bone marrow transplant.
10.00 - 50.00	LD **100/7;** intense symptoms within 5 - 30 mins, latent phase up to several days, then certain death due to failure of circulation (water-electrolyte imbalance).
> 50.00	Death < 50 hours.

Contamination with Radioactive Materials:

There is a common misconception that external radiation sources such as X and Gamma-rays cause internal contamination within the body. This is simply not the case, as contamination cannot occur from the use of sealed sources or X-ray sources. The radiation emitting from such sources passes through the body, leaving behind ionization damage, but not radioactive "contamination", which would add to the naturally occurring materials already in the body. Contamination with radioactive materials can and does occur from reactor accidents like Chernobyl and Fukushima, and from the past atmospheric testing of nuclear weapons. In these circumstances, radioactive materials in the form of dust, aerosols and gasses can spread widely as contaminants through the atmosphere, through the hydrosphere, or into the soil.

Safety Measures with Ionising Radiation

Before a radiation practice can commence, the Regulatory authority must approve that the company carrying out the practice has satisfied certain safety obligations. Part of the process is the development and approval of a Radiation Safety and Protection Plan (RSPP). The RSPP states how the company will operate the radiation practice safely. The safety measures employed when using Ionising radiation and radioactive materials, are based on no harm coming to persons exposed, provided that:
Exposure to Ionising radiation is kept below the dose limits set by the Regulator in each state, and
No radioactive materials are allowed to enter the body.

Several control measures are therefore necessary to achieve these objectives. Whenever any project makes significant use of Ionising radiation or radioactive materials a competent person is appointed with a responsibility for all radiological safety aspects of the work. This person is known as the Radiation Safety Officer (RSO).

The RSO's job is to ensure that the administration of the project is thorough, that people working on it know about the hazards and how to overcome them, and that the radiation levels are regularly monitored. It is very important that doses are also minimised to protect workers who don't use these devices, and to the "general public". In this regard, security of the devices must always be maintained, whether in use, transport, or storage.

The RSO should also ensure that the three main measures to minimise radiation exposure are taken. These measures are:

Time of Exposure

This involves ensuring that personnel are exposed to Ionising radiation for the minimum possible period during their work.

In utilizing time as a protective measure, it may be necessary to set a working time for persons in a high radiation field to prevent overexposure. The time limit can be calculated simply as:

$t = D/d$ hours where D is the dose limit (µSv)
d is the dose rate in the area (µSv/hour)

This is a useful calculation for the RSO, as it defines the maximum dose rate, beyond which the annual dose limit may be exceeded.

Distance

This is made use of by ensuring that personnel remain at the largest possible distance from sources of Ionising radiation. For a point source the inverse square law applies. Put simply, this law says that the dose of radiation from a radiation source decreases with the square of the distance between the source and the person receiving the radiation.

For example, if the distance is doubled the radiation dose received will be one-quarter. Similarly at half the distance, the dose rate will be quadrupled.

$$I_0 \times d_0^2 = I_n \times d_n^2$$

where: I_0 is the original intensity at the original distance d_0, and I_n is the new intensity at the new distance, d_n

Shielding

This involves the use of adequate amounts of shielding materials whenever persons are working in the vicinity of sources of penetrating Ionising radiation. Provision for proper shielding permits individuals to work much closer to a source of Ionising radiation, and for longer periods, than if no shielding is provided. The HHXRF Analysers employed today come with an option for a "backscatter shield". These shields should be used to provide added protection to the user when testing is taking place; for e.g.

- Irregularly shaped samples
- Samples with a low atomic number (Z)
- Samples smaller that the analysis window (typically <10mm diameter)

All suppliers of XRF equipment offer portable work stations or bench type shields, these are ideal when the hand-held device is used indoors and external radiation levels remain no more than background radiation levels. They offer additional safety measures such as interlocks and shielding as well as remote operations. It is important to note that this does not re-classify the analyser, you are still required to be licensed.

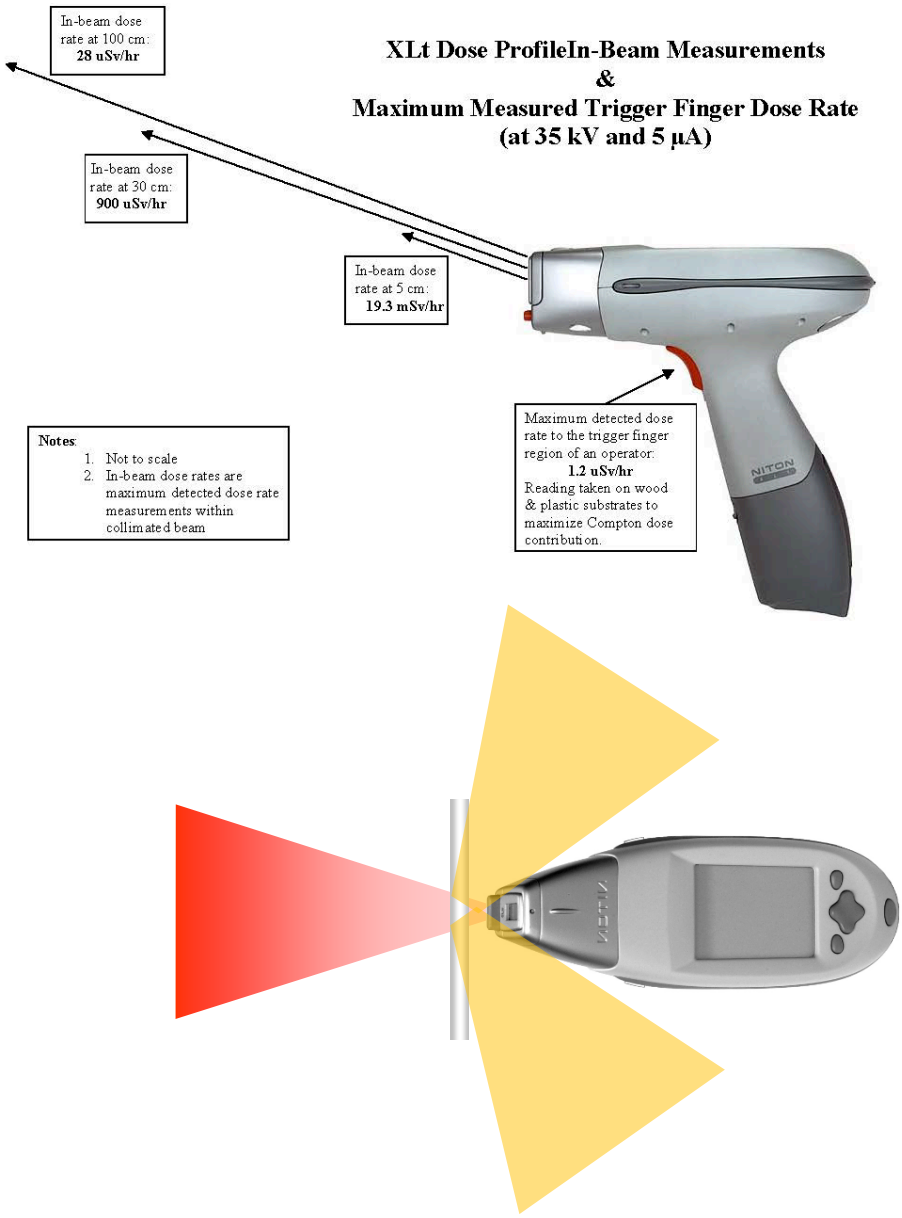
Figure 7 – Accessories available that increase the distance and provide shielding





ALARA is an internationally adopted radiation protection principle. All doses must be kept within regulatory limits and kept as low as reasonably achievable.

Figure 8 - Dose Rate & Profiles (Niton Example)



Summary: How can YOU minimise your dose?

Reduce time	Take good samples to avoid retesting
Increase Distance	Be aware of how your body is positioned, use the 1m extension poles
Use Shielding	Use the back-scatter shield or workstation

Working Rules for HHXRF

All users must be licensed and authorised to use. (Or under training and supervision of a licensed person.

Never Aim the Primary Beam at yourself or others.

- Ensure all pre-operational checks are conducted to avoid unintentional excess exposures.
- Persons not directly involved should be at least 1m away.
- Only use the HHXRF in accordance with the manufacturer's instructions.
- When analyzing low atomic number samples, employ the use of the backscatter shield.
- Ensure the HHXRF is only used for authorised purposes.
- Ensure that the trigger on the HHXRF is only operated when the sample of interest is in place and ready for testing.
- Handle with care so accidental exposure doesn't occur.
- Ensure the sample covers the window before pulling the trigger.
- Never hold a sample with your fingers, annual dose rates can be exceeded during a single sampling time.
- Never leave the HHXRF unattended.
- Ensure that the HHXRF is secured in its transport case after use.

Failure to follow these rules may result in poor quality sample results and/or unplanned radiation exposure.

Pre-operational checks for HHXRF

- Always refer to the operator's manual and the approved Radiation Safety and Protection Plan for a full list of pre-operational checks.
- Check the unit for any signs of physical damage.
- Check all warning labels are fitted and legible.
- Check that the window is in good condition.
- Ensure system start up procedure is completed.
- Check the operating parameters are suited for the tests and the proximity sensor enabled.
- Check no one is in the immediate vicinity.

Operational check

- Check all radiation warning lights are operational.
- Check proximity sensor is operating.
- With the proximity sensor enabled, attempt a "Fresh Air Shot" with the beam pointed in a safe direction and with no sample in front of the window.

If the HHXRF fails any of the pre-operational or operational checks, the apparatus is not to be used and the matter brought to the attention of the RSO. Tag the equipment out of service, remove the battery and secure in the storage.

Never Aim the Primary Beam at yourself or others during pre-operational or operational checks.

Proximity Sensor

The proximity sensor is a safety feature that prevents un-intended exposure when a sample is not in the primary beam. At times this sensor will need to be overridden to enable operations especially on curved or un-even surfaces. Always refer to the Radiation Safety and Protection Plan (RSPP) for details on this operational change and if the Radiation Safety Officer (RSO) is required to approve this.

You are not permitted to modify the apparatus to over-ride any safety features.

Labels

All HHXRF Instruments are required to display the radiation trefoil and words to the effect of "Caution X Rays" DO NOT REMOVE THE RADIATION WARNING LABEL FROM THE ANALYSER.

Figure 9 - Niton Warning Label



Additional safety checks for HHXRF

The person/s responsible for three monthly safety checks are usually listed in the RSPP attachments. Usually this will be the RSO, however these checks may be delegated to a licensed user.

- Every 3 months, check radiation warning signs as required by the radiation safety standard.
- Every 3 months, check radiation warning lights as required by the radiation safety standard.
- If used in a premise, an area warning sign is visible prior to entry.
- The manufacturer's operating manual is available.

The condition of the analyser by:

- Checking for any damage or wear.
- Ensuring it operates IAW the manufacturer's instructions.
- The sample proximity sensor operates properly.

Certificates of Compliance

The RSO also arranges for the mandatory compliance assessment for the HHXRF Analysers, these must be carried out prior to first use and at intervals not to exceed three years.
It is your responsibility to check that there is a current certificate of compliance for the analyser.
This information can generally be checked by looking inside the transport case for a Certificate of Compliance.

Personal Monitoring

Personal dosimeters (Film Badges) must always be worn during use of HHXRF if required by the RSPP.

- When not being worn, they are to be placed away from any source of radiation and direct sunlight etc. (on a designated pegboard or similar.)
- Dose rates from HHXRF are usually expected to be below 1mSv per year however some Possession Licensees will elect to monitor personnel involved in the use of HHXRF.

Transport

There are no special requirements for Transport of a HHXRF that employs an X-Ray tube as the radiation source.
The security of the HHXRF is of utmost importance and it is highly recommended that the transport case be kept locked whenever it is being transported.

Storage

When not in use, HHXRF Analysers should be stored in a location with restricted access, e.g., a locked cabinet. A logbook shall be available that can have a sign out/sign in sheet by authorised and licensed users.

Repairs & Maintenance

Only repairs and maintenance intended by the manufacturer to be done by the user are to be performed on HHXRF Analysers, this includes cleaning and changing the window.
All other maintenance and repair work is to be conducted by the manufacturer.
Do not ever attempt to repair a faulty HHXRF Analyser yourself.

The Radiation Safety & Protection Plan

The Radiation Safety & Protection Plan identifies the hazards and how to deal with the hazards specific to use of HHXRF. The RSPP details how the company will conduct the radiation practice.
It will include details of the radiation sources and obligations of the

- Possession Licensee,
- the Radiation Safety Officer and
- Licensed Users.

Some of the RSO duties will include:

- 3 monthly checks of the equipment to ensure continued compliance.
- Provide or arrange for training about radiation hazards and safe working practices.
- Ensuring that the likely maximum radiation doses a person could receive are within the limits prescribed by the *Regulation* and are as low as reasonably achievable.
- All relevant people have read, understood and are complying with the RSPP.
- Details of the radiation sources are accurate.
- Radiation monitoring devices are available and in good working order.
- All records are being maintained.

User Obligations (Radiation Safety & Protection Plan)

It is your obligation as an intended User to read and understand the plan.
The Radiation Safety & Protection Plan for your practice will detail all obligations for licensed and authorised personnel. Always refer to the RSPP and clarification from the RSO for details. Specific requirements may include:

- Read and understood the Radiation Safety and Protection Plan.
- Wear all safety devices as directed by the Radiation Safety and Protection Plan.
- Ensure that the field portable analysers are only used for authorised purposes.
- Ensure that the field portable analysers are energised only when the sample is to be analysed.
- Never operate the field portable analysers while a safety feature is removed, modified or inactivated.
- Never change or adjust the sample, collimator or analysing crystal while a primary X-ray beam passes through that collimator or is incident on that sample or crystal, unless the change or adjustment can be done remotely without intercepting the primary beam.
- Never leave the apparatus unattended while it is in the operational mode.
- If the apparatus is left unattended an automatic trigger lock is initiated after a few minutes; all software will be shut down at completion of use that only authorised trained staff has access to password lock on XRF.
- Never try to defeat the safety interlocks; and
- Initiate actions as detailed in this plan if potentially hazardous situations arise from X-ray beams that may be emitted due to a defect or misalignment of the apparatus or for any other reasons.
- Ensure their License and authorisations are current.

Common Questions and Answers

Q. When I'm shooting a piece of pipe or valve on a rack or on a tabletop, is there any exposure to people standing 1m away from the analyser?

A. Even a thin amount of a dense metal (excludes Aluminum Alloys) sample 3 to 4mm thickness is enough to completely attenuate the emitted x-ray beam. Shooting a piece of material that covers the sampling window on the analyser completely shields any bystanders from radiation exposure.

HOWEVER, in line with safe work practice techniques, keep others at least 1m away.

Q. If I forget to lock the trigger and pick up the analyser and accidentally pull the trigger, is that dangerous to nearby personnel?

A. No, although this is an example of unintentional misuse. It may produce negligible radiation exposure to nearby personnel. For an exposure to occur, the following events must occur.

- The analyser must be held so that a bystander is standing in the x-ray beam being emitted. Just being near the analyser will not cause unintended exposure.
- It would require failure of the proximity sensor.
- The bystander must be within one meter from the nose of the analyser to receive any appreciable dose.

If all these conditions are true, the dose received by a bystander can be in the order of 0.2mSv.

Incidents

Any incident or accident adversely or likely to adverse the health or safety of any person because of an unintended exposure. The following situations are examples of reportable incidents.

- X Rays are generated through failure of the proximity switch or failed to terminate.
- Unintended exposure to a person has occurred.
- Theft or vandalism.

What to do in the event of an incident?

- Turn off the equipment.
- Remove the battery.
- Secure the equipment and tag with description of problem.
- Report the incident to the RSO.
- Unintended exposure to a person has occurred.
- Incident Reporting

An incident report is to be submitted to Radiation Health (at the address below) by the Licensee within seven (7) days of the incident. The report will include:

- A description of the Incident.
- Estimates of radiation exposure to individuals.
- Action taken.
- Changes to the Radiation Safety Plan to prevent a recurrence.

https://www.health.qld.gov.au/system-governance/licences/radiation-licensing/contact/incident-notifications

Attachment 1 - Handheld Analytical Radiation Apparatus

ARPANSA Code of Practice	**ARPANSA Code of Practice for protection against Ionizing Radiation emitted From X-ray analysis equipment (1984) -RHS 9**

*Extracted from APRANSA Radiation Health Series No.9 – ARPANSA Code of Practice for protection against Ionizing Radiation emitted from X-ray analysis equipment (1984)

****Please also refer to your Company's approved Radiation Safety and Protection Plan, as some items listed below may differ and are specific to your radiation practice.****

6. Working Rules

6.1 Scope of this section

The working rules given in this Section are considered necessary to achieve a similar standard of safety for each type of X-ray analysis unit. To this end, additional procedures and precautions are required in the use of analysis unit; lacking certain instrumental safety features. Nevertheless, measures should be taken to ensure that each unit meets the standard of safety for the type of unit requiring the fewest working rules, i.e. an enclosed unit.

6.2 General Working Rules for all X-ray analysis units

6.2.1 Each person who uses an X-ray analysis unit shall avoid exposing any part of the body to a primary X-ray beam. If actual or suspected exposure has occurred the appropriate course of action should be taken.

6.2.2 No person shall allow the X-ray tube of an X-ray analysis unit to remain energized unless all warning lights, as required by this Code, are operating correctly.

6.2.3 No X-ray tube shall be energized:

(a) while outside its protective tube housing, or
(b) with an unshielded aperture in the tube head or protective barrier.

6.2.4 No sample, collimator or analysing crystal shall be changed or adjusted while a primary X-ray beam passes through that collimator or is incident on that sample or crystal unless:
(a) the sample, collimator or crystal, during and after the change or adjustment, is within a shielded enclosure, and
(b) the change or adjustment is done by remote means from outside the enclosure.

6.2.5 Immediate measures shall be taken to remove potentially hazardous situations arising from X-ray beams that may be emitted due to equipment defect, misalignment or any other reason.

6.2.6 A list of additional working rules shall be drawn up for each X-ray analysis unit where

Attachment 1 (Cont.) - Handheld Analytical Radiation Apparatus

necessary to ensure safety. This is of particular importance for units which do not meet the requirements of this Code for enclosed or partly enclosed units. (See 6.4)

6.2.7 The necessary operations of the X-ray analysis equipment shall not be performed by inexperienced persons unless under direct supervision of an experienced operator.

6.2.8 Alignments or adjustments shall not be carried out visually while the X-ray tube is energized, unless a viewing system is used which is shielded or designed to prevent exposure of the eye or other parts of the body to the primary beam.

6.2.9 The X ray analysis unit shall not be operated, by inactivation of an interlock or with part of its enclosure removed without prior approval of the statutory authority or unless the X-ray tube is wholly enclosed by the tube housing with all apertures completely covered by interlocked shutters and/or fixed covers.

6.2.10 If under prior approval of the statutory authority (see 6.2.9) the X-ray analysis unit is operated with an interlock inactivated or part of its enclosure removed exposing the primary beam, the following rules shall be applied:

6.2.10.1 The number of persons who carry out the alignment of a camera or sample in an X-ray beam, or who make any adjustment or alteration to the analysis equipment while the X-ray tube is energized, shall be the minimum necessary to carry out the operation safely.

6.2.10.2 An experienced person not engaged in the operations specified in 6.2.10.1 shall observe the procedures and warn each operator doing them of any operation which might lead to any part of the body being exposed to a primary beam or any excessive level of leakage radiation or scattered radiation.

6.2.10.3 When the X-ray tube is energized, access of non-essential personnel to the room containing the unit shall be prevented by physical barriers. A sign warning of the operations in progress shall be placed at each entrance to the room containing the unit.

6.3 Working Rules for partly enclosed units

The working rules for each partly enclosed unit shall include those given in 6.2. All working rules given in 6.2.10 shall be implemented whether or not an interlock is inactivated or shielding structure is removed.

Attachment 1 (Cont.) - Handheld Analytical Radiation Apparatus

6.4 X-ray analysis units not complying with Section 5 of this Code

Each X-ray analysis unit which does not comply with the requirements of Section 5 of this Code (i.e. does not meet the requirements for an enclosed or partly enclosed unit) shall not be used until modified to meet those requirements, unless the user has prior approval of the appropriate statutory authority to do so for an interim period. When such approval is given a set of working rules approved by the statutory authority shall be drawn up for use pending the required modifications or replacement by a unit that complies with Section 5.
These working rules shall be designed to achieve the same standard of safety as the required modifications of the equipment, shall be prominently displayed on or near the X-ray analysis unit, and shall be rigorously implemented. The interim working rules shall include rules and requirements as follows:

6.4.1 The rules required in 6.3 for partly enclosed units shall be included, and implemented whenever the unit is used.

6.4.2 Supplementary interim rules shall be included to minimize the risk that any person will be exposed to a primary X-ray beam from the unit or otherwise receive a dose of radiation in excess of the recommended dose limit.

6.4.3 A checklist of step-by-step procedures shall be prepared and used during the following operations:

(a) before initiating an exposure
(b) during an exposure
(c) in terminating an exposure, and
(d) during any non-routine operation of the unit, such as alignment of an X-ray beam.

6.4.4 The unit shall not be operated if any person other than those essential to its operation occupies the cubicle, room or area in which the unit is placed.

6.4.5 No alternation should be made to the analysing equipment in use with the unit unless the X-ray tube is de-energized.

6.4.6 Interim working rules shall include the requirements for siting given in 5.5.2 and 5.5.3, with the requirement 'should' being replaced by 'shall',

6.4.7 The requirements of Section 7 (radiation monitoring) shall be incorporated in the working rules with the following amendments:

6.4.7.1 The requirement 'should' in 7.2.1 and 7.2.2 shall be replaced by 'shall'.

6.4.7.2 Periodical monitoring shall be performed not less than once in each month and the unit shall be thoroughly examined for hazards and all safety features checked at least once in each week. This requirement is the same as that for a partly enclosed unit (see 7.3.3).

Attachment 1 (Cont.) - Handheld Analytical Radiation Apparatus

Emergency Procedures

In the event of an actual or suspected exposure of any person to a primary beam of an X-ray analysis unit the following should be carried out.

Switch off the X-ray analysis unit.
Do not take remedial action to correct the particular fault, if any, that caused the exposure.
Post assessment of the absorbed dose may be more difficult if the fault is corrected.
Leave a sign on the unit to indicate that the unit should not be used or altered in any way.
Notify the following of the exposure:
(a) The user
(b) The Radiation Safety Officer
(c) The statutory authority
Refer the exposed person for medical examination

Attachment 2 - C.2 Requirements for hand-held analytical radiation apparatus

Radiation Safety Standard	Standard for radiation sources-industrial, mining, manufacturing, and other practices (2021) Section C.2 (Extract)

The following table sets out the minimum test requirements for hand-held radiation apparatus used to carry out chemical or physical analysis.

Test	Compliance Test	Criteria for Passing the Test
C.2.1	Radiation Dose rate	When the X-ray tube is energised, and operating at its maximum output, the radiation dose rate must not exceed 10µGy.h^{-1} at any accessible point 5 centimetres from the external surface.
C.2.2	Radiation warning label	The external surface of the radiation apparatus must be durably and legibly marked with a label incorporating the following information in a conspicuous location: Radiation warning sign (trefoil) The word “caution” or “warning” The lettering and symbol must be in black on a yellow background.
C.2.3	Unauthorised operation	The radiation apparatus must be key operated so the X-rays are not produced when the key is removed. For the purpose of this test, a key could be a magnetic card, numeric panel, USB key, password or similar.
C.2.4	Exposure control	An exposure control must be provided which requires: (a) continuous actuation (e.g. a trigger); or (b) a pre-set time interval. Emission of X-rays must not be possible after the timer has expired or the trigger is released.
C.2.5	Warning lights	The radiation apparatus must be fitted with an indicator which illuminates only if the X-ray tube is energised.
C.2.6	Proximity sensor	As a default setting, the radiation apparatus must not emit X-rays if the apparatus is not in the “measurement” position (e.g. pushed against the sample being analysed).

Attachment 2 (Cont.) - C.2 Requirements for hand-held analytical radiation apparatus

C.2.7	Local enclosure	If a local enclosure is provided for use with the radiation apparatus, the following must be complied with: (a) the radiation dose rate outside this enclosure must not exceed 2.5µGy.h^{-1} when the X-ray tube is operated at its maximum output; and (b) a durable and legible radiation warning label is visible in a conspicuous location, containing the information: • Radiation warning sign (trefoil) • The word “caution” or “warning” • The lettering and symbol must be in black on a yellow background; and (c) there is a visible indication which illuminates only if the X-ray tube is energised.

Document Control

Revision History

REV	DATE	COMMENT	AUTHOR	APPROVED
3.2	15/02/2022	12M Review	C. Browne	K. Lawrenson
3.3	30/08/2023	12M Review, formatting changes	P. Thompson	K. Lawrenson
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