Radiation Safety for Intending Level 2 Users of Analytical X-Ray Unit (Hand-held)



Objectives

RADIATION SAFETY AWARENESS with reference to handheld analyzers

- Describe the roles of:
    - Regulatory Authorities *(Qld Health Radiation Health Unit, Enforce the Radiation Safety Act and Regulations, Issue Licenses)*
    - Radiation Safety Officer (RSO) *(On-Site and reports to the Possession Licensee on Training, Compliance, Reporting)*
    - Licensed user *(Operate IAW RSPP and License Conditions)*
- Describe how to minimise dose rates during use *(Time, Distance, Shielding)*
- State the rules associated with HHXRF *(RSPP, License, OEM Manual)*
- State the checks associated with HHXRF *(RSPP, OEM Manual)*
- State Emergency Procedures *(RSPP, Shut down, remove battery and access, report to RSO*)

Why is this course needed ?

The Licensed User has obligations under the Radiation Safety Act 1999 that they must be made aware of.

In order to fulfill the obligations as a Licensed user under the Act, the user needs to understand the implications of careless use and or disregard of safe work practices.

Analytical X-Ray Unit (hand-held) Use Licence for Chemical Analysis

Referred to in course notes as HHXRF

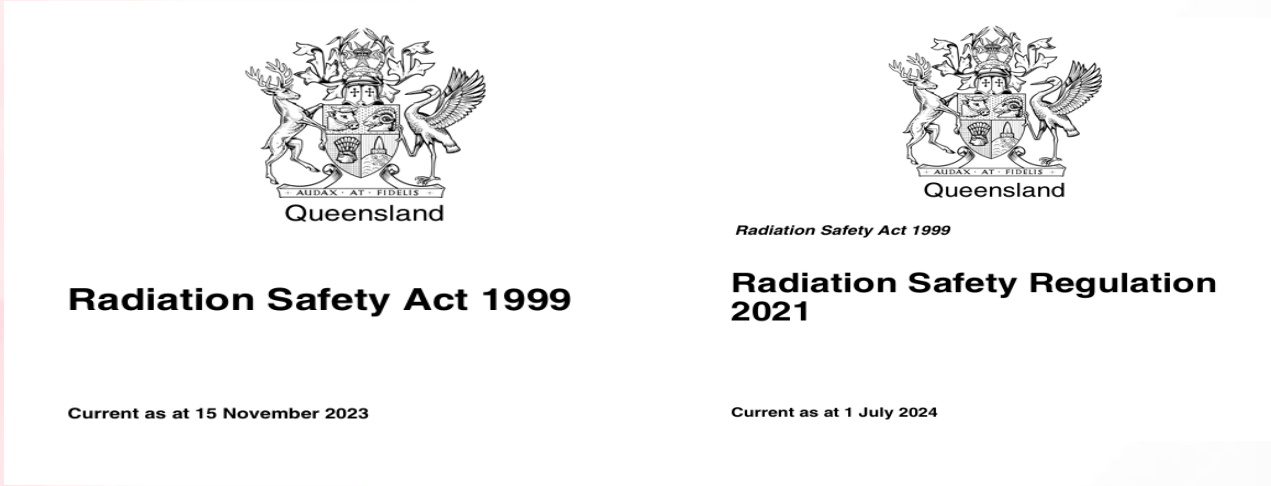
Origins for Legislation

- International → National (Federal) → State
- International Commission on Radiological Protection (ICRP)
  - independent, international organisation from approximately thirty countries (including Australia)
  - Made up of leading scientists and policy makers in the field of radiological protection
  - Developed the international system used world-wide as the common basis for radiological protection standards, legislation, guidelines, programmes, and practice
- National (Federal)
  - Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
  - "Harmonisation" between states and territories → National Directory for Radiation Protection (NDRP)
  - Codes of Practice (NHMRC Guidelines, Radiation Health Series, Radiation Protection Series)

State Legislation (Queensland)

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

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.



Some Obligations of Licensed Users under the Act

- Limiting of Radiation Exposure to other persons
- Ensuring health safety & protection of environment
- Compliance with conditions
- Compliance with Acts, Regulations and Codes of Practice

- There are penalties for breaches of the legislation as a licenced user. You are personally responsible and liable under the Act.
- *As of 1st July 2024, a penalty unit's value is $161.30*
- Under the Act, Part 2 Section 13, a person must not use a radiation source, unless that person is allowed to use it under a use licence
  - (a) A radiation source that is not a security enhanced source – 400 penalty units $64,520; or
  - (b) A portable security enhanced source – 2500 penalty units $403,250

  Note: Using a HHXRF unless under training or supervision is classed as using a radiation source that is not a security enhanced source

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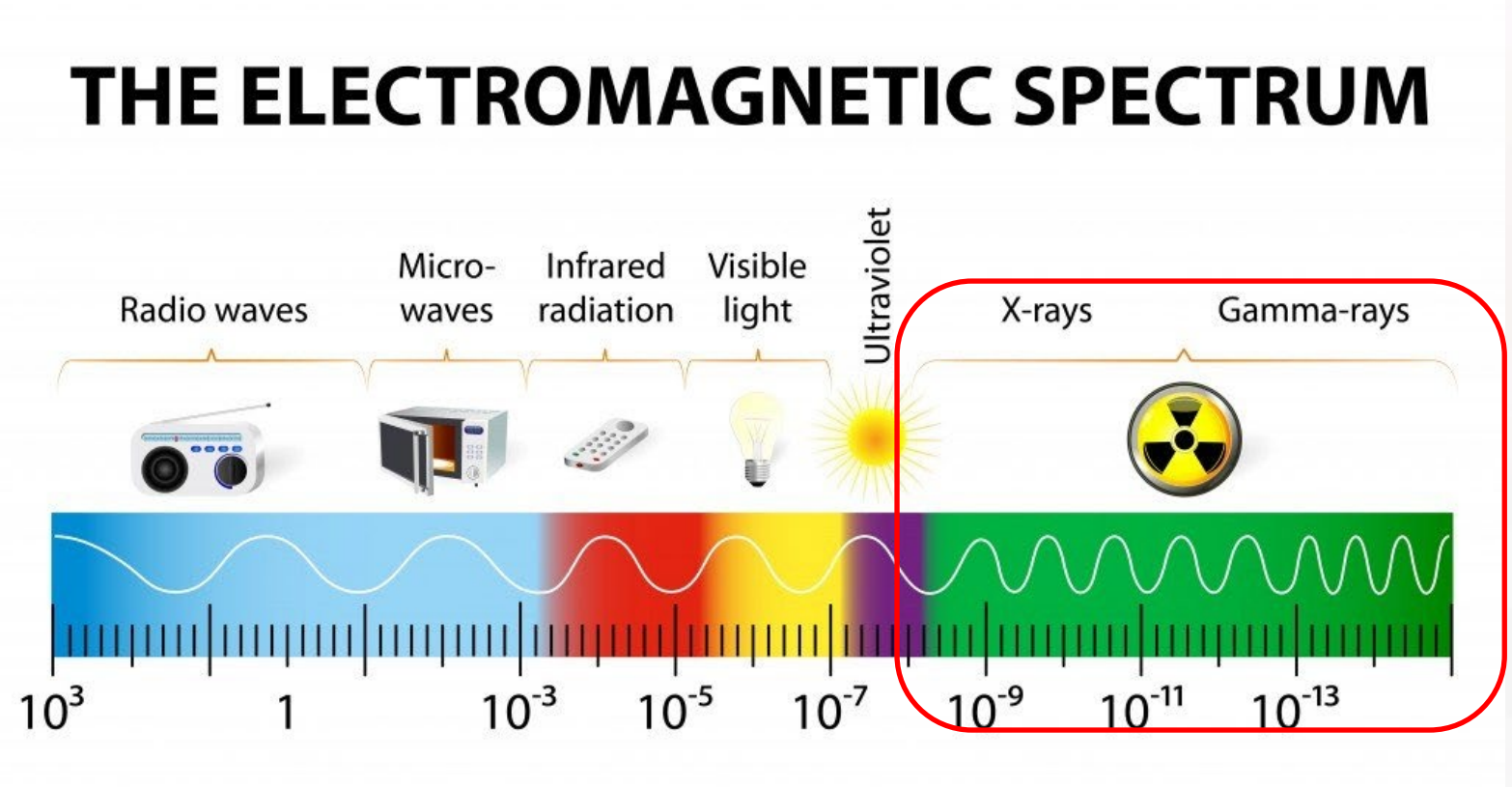
Competencies for Use License

In order to obtain a Use Licence, you must provide confirmation that you have undertaken:

1. An approved course,
2. Demonstrated safe, practical use of the Analytical X-Ray Unit (hand-held) or HHXRF under supervision and,
3. Submitted the correct application and paid the fees

Course Notes p.3

Non Ionising Vs Ionising



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What is Ionising Radiation ?

In the ionisation process, an energetic radiation particle collides with one of the electrons in an atom in the material and knocks the electron out of the atomic cloud.

This process leaves the atom with a nett electrical charge which makes it very reactive.

The nett result is that the atom is now ionised, while the ejected electron will attach to another atom, forming an ion pair.

This affects the chemical reactions which occur in living tissue at a cellular level, particularly in our DNA resulting in either impairment or death of the cells.

Why Do We Use Radiation?

- Radiation sources[1] are used despite:
  - High cost,
  - Regulations, and
  - Opposition on anything nuclear

Basically, we use radiation sources because there is no other alternative that will give us real time results in the Field.

Note 1:

A Radiation source can refer to either a radioactive isotope or an apparatus that electrically generates radiation

What Type of Radiation is used with the HHXRF?

The Radiation sources that are used in Analytical X-Ray Unit (hand-held) or HHXRF are X-Rays, a form of electromagnetic radiation. Used widely for their ability to see through or penetrate a diverse range of materials.

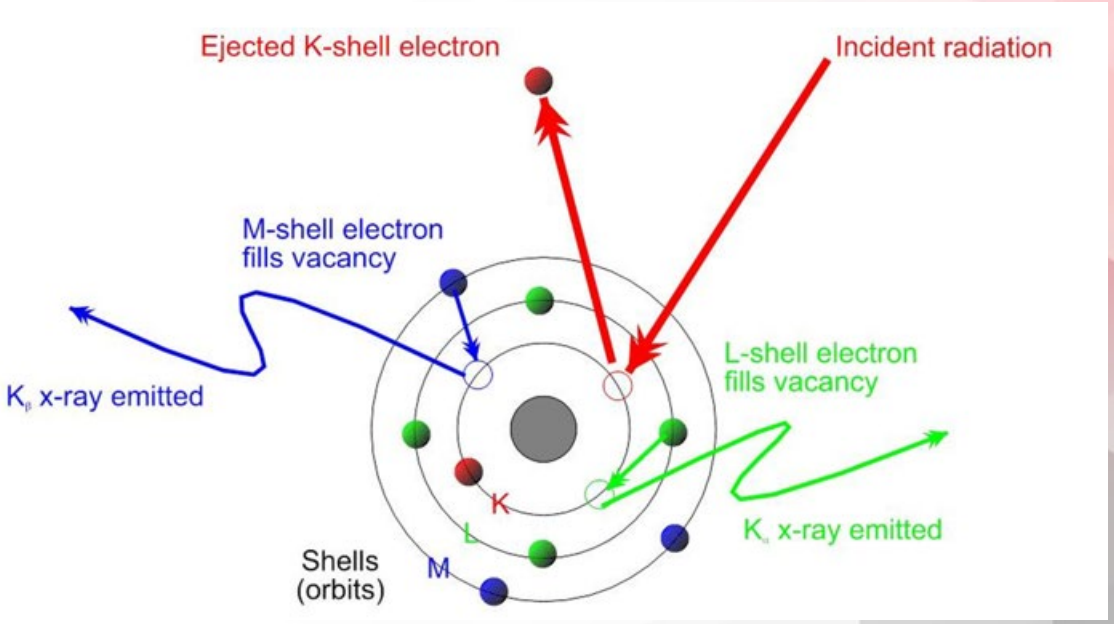
Older type analysers used a sealed radioactive substance, however, all new generation hand-held analysers utilize an Xray tube.

XRF Technique

- 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.
- XRF can typically analyse elements from sodium to uranium in concentrations ranging from parts per million to high percents, in solids, liquids, and powders.

XRF Technique

- An X-ray beam with enough energy to affect the electrons in the inner shells of the atoms in a sample is created by an X-ray tube inside the analyzer. The X-ray beam is then emitted. The X-ray beam interacts with the atoms in the sample by displacing electrons from the inner orbital shells of the atom.
- This displacement occurs as a result of the difference in energy between the primary X-ray beam emitted from the analyzer and the binding energy that holds electrons in their proper orbits; the displacement happens when the X-ray beam energy is higher than the binding energy of the electrons with which it interacts.

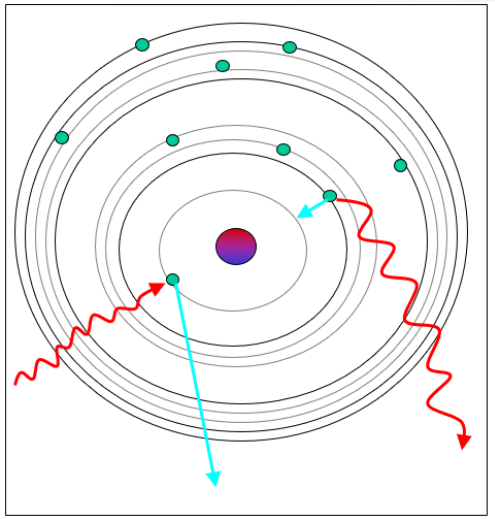


XRF Technique

- 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**.



- A source X-ray strikes an inner shell electron. If at high enough energy, it is ejected from the atom.
- Higher energy electrons cascade to fill vacancy, giving off characteristic fluorescent X-rays.

Radiation Protection

- Under normal conditions, the radiation exposure from the use of Analytical X-Ray Unit (hand-held) or HHXRF is low, however, we need to ensure that our exposure to the sources from radiation are kept low and that has to do with the way we use the analysers.

- Poor work practices have been shown to increase the user's exposure to radiation sources.

- Because little is known about the long-term health effects, we should ensure we don't exceed the limits as set by the regulatory authority and that our exposure is minimised. (As Low As Reasonably Achievable)

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The Concept Of “Radiation Dose”

The absorbed dose is the Gray (Gy) is defined as the amount of radiant energy deposited in the body, ie Joules / kg.

The equivalent dose is the absorbed dose weighted [note 1] for the harmful effects of the type of radiation and is called the Sievert (Sv).

Often expressed as mSv for annual dose, and as $\mu Sv.h^{-1}$ as a dose rate. (1000 µSv = 1 mSv)

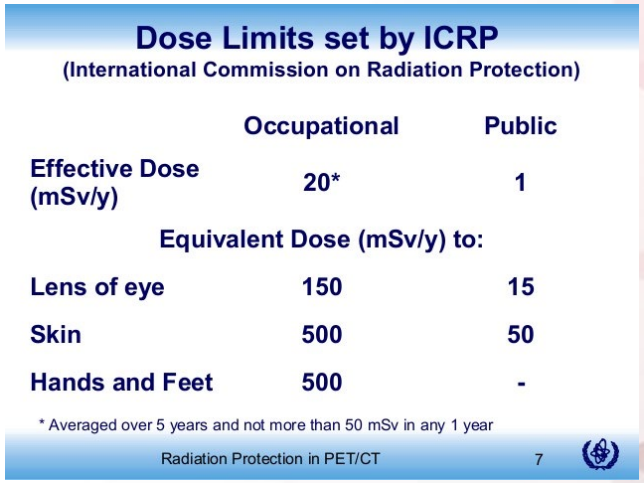
The effective dose is the equivalent dose weighted [note 2] for the radiosensitivity of the different tissues and organs.

Note 1 – Weighing factor for X-Rays =1

Note 2 – In an industrial setting a whole-body dose of 1 is applied how-ever dose limits to the hands is 25 times higher than the whole-body dose for a radiation worker

Where do Dose Limits come from?

- The International Commission for Radiological Protection is a not-for-profit organization.
- It is an independent, international organization with more than two hundred volunteer members from approximately thirty countries on six continents, who represent the world's leading scientists and policy makers in the field of radiological protection.
- ICRP Recommendations for Dose Limits are adopted by member countries



ARPANSA Radiation Protection Series



Schedule A Dose limits for occupationally exposed persons

The occupational dose limits for ionising radiation are as follows:

Type of limit	Limit (18 years and over)[1]	Limit (more than 16 years but under 18 years)[1,5]
Effective dose	20 mSv per year, averaged over a period of five consecutive years[2]	6 mSv per year
Annual **equivalent dose** to the lens of the eye	20 mSv per year, averaged over a period of five consecutive years[3]	20 mSv per year
Annual **equivalent dose** to the skin[4]	500 mSv per year	150 mSv per year
Annual **equivalent dose** to the hands and feet	500 mSv per year	150 mSv per year

Schedule B Dose limits for members of the public

The public dose limits for ionising radiation are as follows:

Type of limit	Dose Limit[1]
Effective dose	1 mSv per year[2]
Annual **equivalent dose** in the lens of the eye	15 mSv per year
Annual **equivalent dose** in the skin[3]	50 mSv per year

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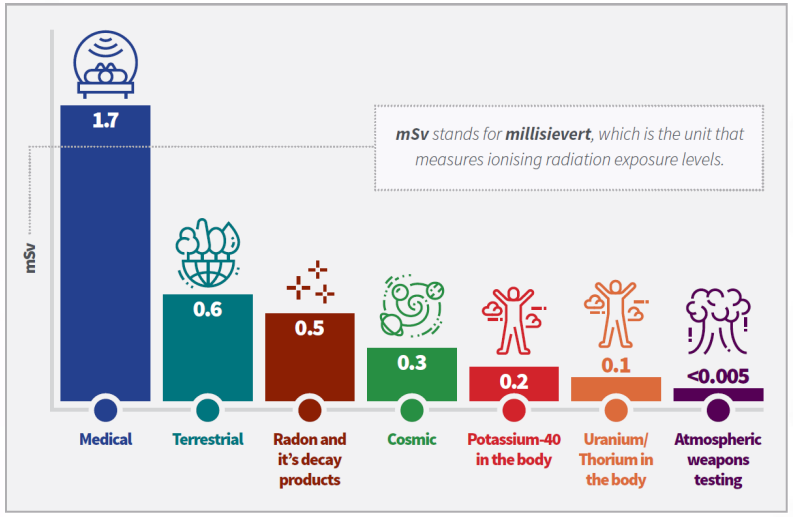
Background Radiation

1. External: Soil & rocks, Radon, Cosmic Radiation, Food and Beverages
2. Internal: K-40, U, Th & their progeny.
3. Man-made: medical procedures, “fallout” from atmospheric testing of weapons, Reactor incidents.

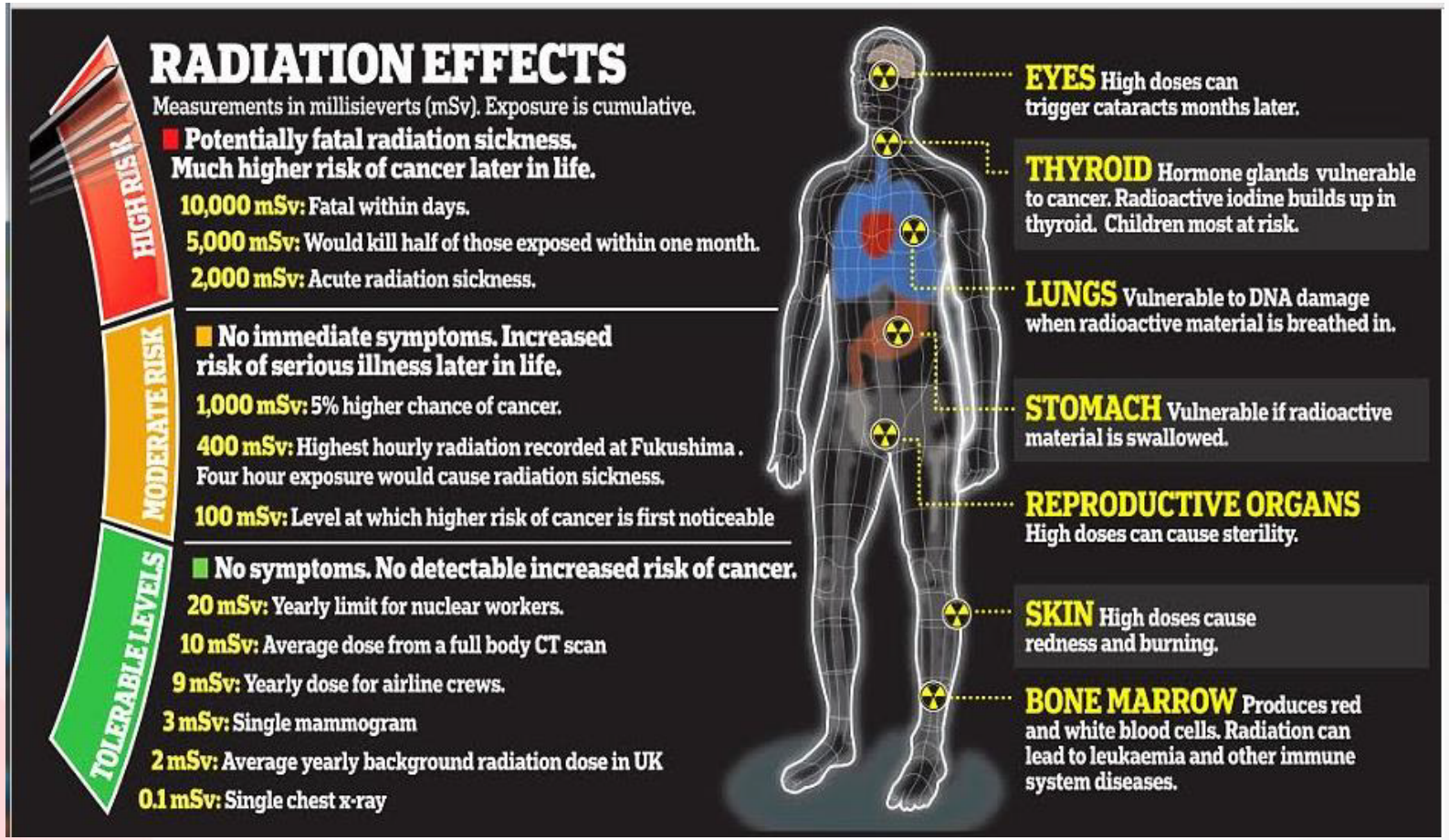
The total is around 1.5 – 2 mSv per year, or around 0.15 μSv/Hr.



Radiation Injuries

- We are quite used to the damaging effects of the ultraviolet component of solar radiation (sunburn and risk of skin cancer.) We also know from experience that we cannot sense this radiation directly, and that the perception of sunburn starts after the damage has been done.
- It is not surprising then, that ionising radiation has similar effects, as it borders on UV in the spectrum.
- It is possible to get a fatal radiation dose if one is exposed to a very large amount of ionising radiation in a short time.
- Similarly, the risk of cancer increases with the level of exposure to radiation, and inversely with the age of person exposed. By law, you must be 18 years old to work with radiation, and medical exposures are limited to justified cases only.

Radiation Effects



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Damaging Effects

- 1Sv or 1,000mSv is a moderate dose level for a single whole-body dose which will cause symptoms of radiation sickness to appear in most people.
- At doses of 5 to 8 Sv all exposed persons will die of radiation sickness in the following 4 weeks even with specialised medical care.
- Low doses of less than 100mSv do not cause immediate harm but there are some cumulative effects that are of concern if such doses are repeated.
- If you were to receive your annual limit of 20mSv over a long period of time the risk is considered to be proportionally less and the risk of cancer is around 1 in 1,000.

ALARA: As Low As Reasonably Achievable

Analytical X-Ray Unit (Hand-held) or HHXRF Number One Rule

Never aim the primary beam at yourself or any other person.

Radiation Protection

Planned Exposure Situation - Dose Limits

Practical means of limiting external exposure include:

- Reducing exposure time
- Increasing the distance from the source, and
- Use of shielding

Course Notes p.13

Radiation Protection

– Planned Exposure

Time

- The radiation dose received varies directly with time, so, if you:
  - Halve the time near a source, you halve the radiation dose, and
  - Double the time near the source, you double your radiation dose.

Dose rate × time = Dose

10 $\mu Sv.hr^{-1}$ × 2 hour = 20 μSv

10 $\mu Sv.hr^{-1}$ × 8 hour = 80 μSv

Check your exposure times in the equipment set up, is it possible to get the required results in a 10 second scan rather than 30 seconds?

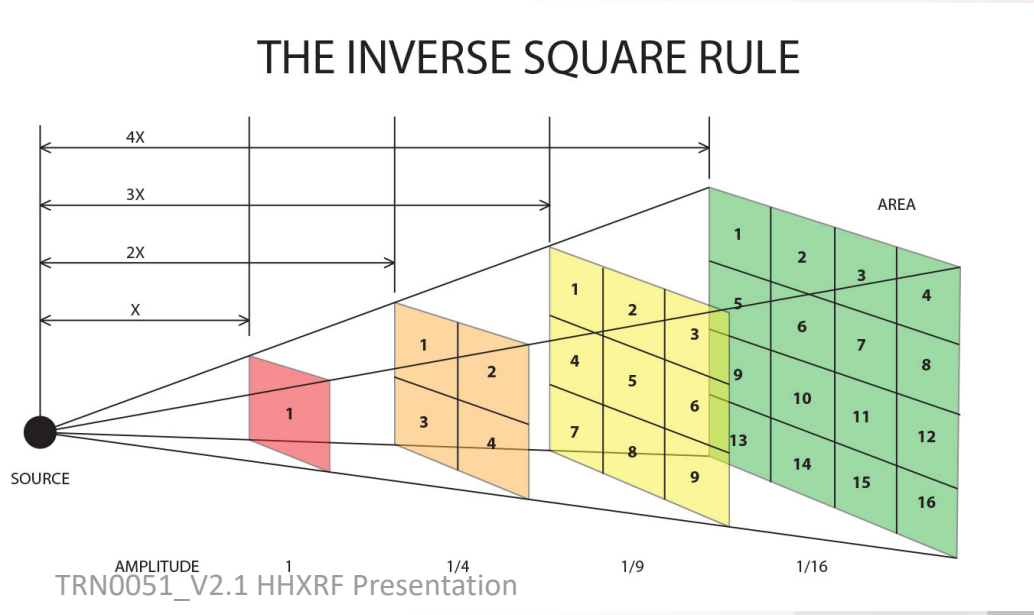


Radiation Protection
– Planned Exposure

Distance

- The intensity of radiation from a radiation source decreases as the distance between the receptor (you or your survey meter) and the source increases.
- The way in which the intensity of the radiation changes with distance is called the *Inverse Square Law*. The name describes the way in which the intensity of the radiation decreases when the distance from the source increases (inversely proportional).

- **Double the distance away - dose rate is Quartered**
- **Half the distance closer - dose rate is Quadrupled**



Radiation Protection – Distance

- The intensity of the radiation change depends on the change in distance squared. This law is defined by the following equation:

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

  - 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



If the 1m extension with remote trigger is used and you want to calculate the

I_n – New intensity (Dose Rate)

Use the following

$$I_n = \frac{I_0 \times {d_0}^2}{{d_n}^2}$$

Based on the XLt Dose profile, dose rate would be approximately 0.2 $\mu Sv.h^{-1}$

Radiation Protection

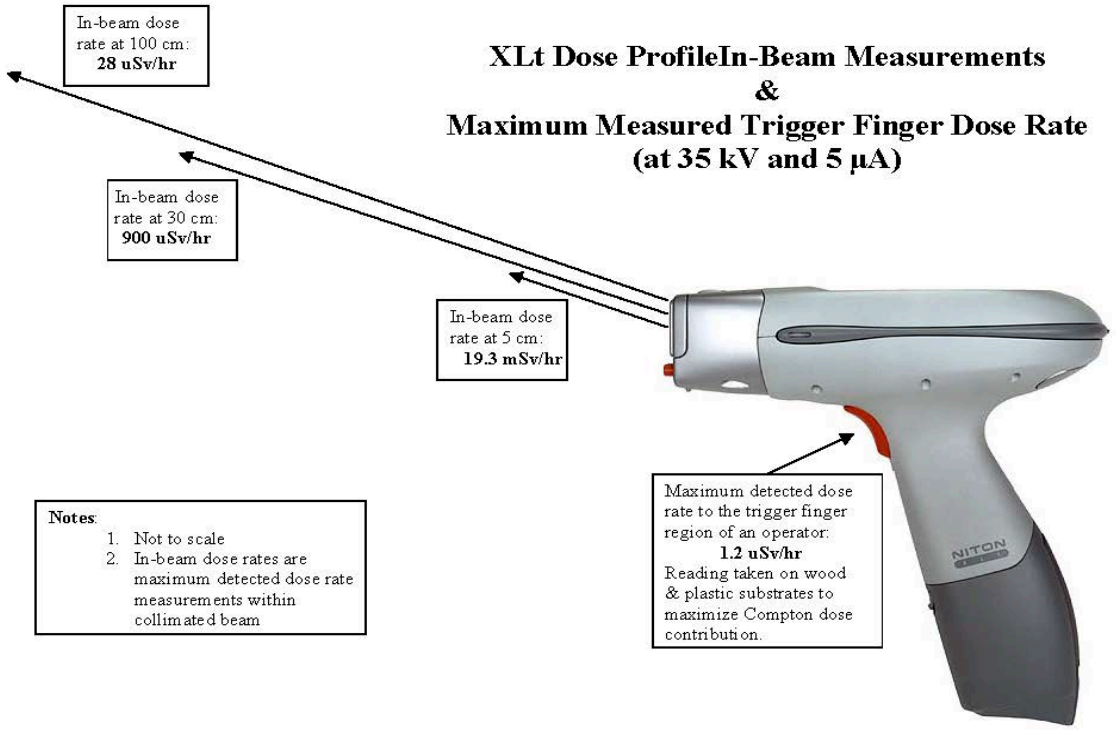
– Shielding

If your laboratory does not use a bench type shield, it is important that you consider what is behind the sample being taken. Ensure that the X-Ray beam will not contact any part of your body or others close by.

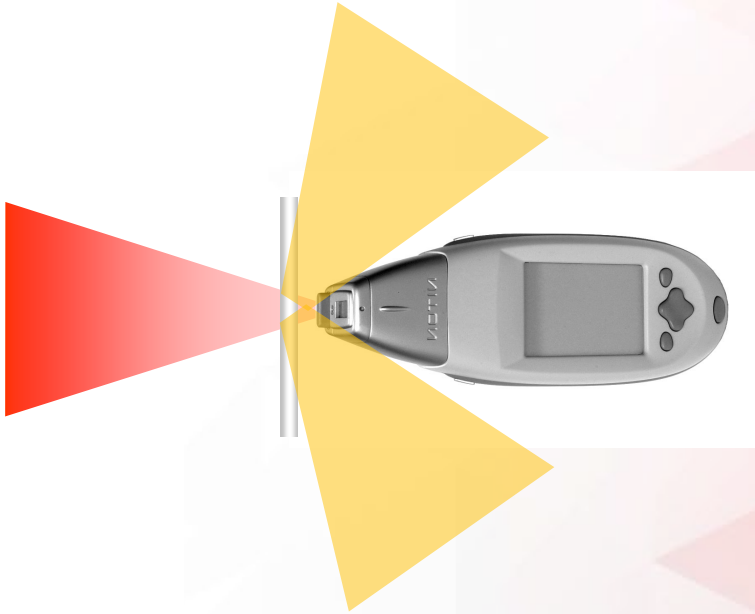




Dose and Beam Profiles



XLt Dose ProfileIn-Beam Measurements
&
Maximum Measured Trigger Finger Dose Rate
(at 35 kV and 5 µA)



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Warning lights during operation



Model: Niton XL3t

Working rules Analytical X-Ray Unit (hand-held) or HHXRF

Common Pre-checks (prior to fitting battery)

- Ensure all casings and screws are securely fastened
- Check warning labels are intact and legible
- Check for any damage
- Check window is fitted and in good condition

Upon initial start up

- Attempt a “fresh Air Shot” with proximity switch enabled
- Check the warning lights are operating
- X-Rays terminate when the trigger (dead-man) is released or
- If the dead-man switch is disabled, the X-Rays terminate after a set time

NEVER AIM THE PRIMARY BEAM AT YOURSELF OR AT OTHERS



The Proximity sensor

- The Proximity sensor is an important safety feature, and it is designed to terminate X-Rays if there is no sample detected in front of the window, or when the instrument is pulled away from the sample before the test time has expired.
- This important safety feature can be disabled or overridden in some Makes and Models of HHXRF analysers only in certain circumstances.
- It is important to understand that you must refer to your Radiation Safety and Protection Plan and RSO before over-riding this function.

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

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Radiation Incident

- Apparatus fails any of the Pre-Operational Checks
- Unit fails “Fresh-Air Shot”
- X-Rays Fail to terminate
- An unintended exposure to a person
- Theft or vandalism

Remove the battery and secure the apparatus then contact the RSO

Remember, with analytical x-ray unit (hand-held) or HHXRF, if you remove the power source, no x-rays can be generated!

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Apparatus Warning Labels



Must be displayed and legible

Working rules Analytical X-Ray Unit (hand-held) or HHXRF - Continued



Ensure that the apparatus is energized only when the item of interest is in front of the instrument and potential for backscattered radiation is minimised;



Never attempt to open the apparatus while it is in the operational mode;



Never leave the apparatus unattended while it is in operational mode;



The device will normally be remotely operated using a test stand in the configuration recommended by the manufacturer. IF the sample is too large or irregular, the apparatus must be used with a backscatter shield.



If the device beam fails to shut off when no sample is present, stop work immediately, ensure that the device is turned off, isolated and inspected by an authorised person.



Ensure that the instrument is in password mode if the apparatus is not used immediately; and



NEVER TRY TO DEFEAT THE SAFETY INTERLOCKS



Report any operating problems to the RSO immediately.

Personal Monitoring Devices (PMD)

- It is the Possession Licensees obligation to provide personal monitoring devices to persons who could be exposed to an annual dose that exceeds the general public limit of 1mSv.
- Your Radiation Safety and Protection Plan (RSPP) will state if the use on personal monitoring (passive or active) is required.
- 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.
- As a User, you are obligated to wear your personal monitoring device whenever you are exposed to sources of radiation during the course of your work.
- PMD’s are easily damaged by heat and moisture.
- Only wear your own dosimeter and return it to storage when not in use.

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The RSPP

- It is a requirement under the Act that a Radiation Safety & Protection Plan is developed.
- The Radiation Safety & Protection Plan describes how the radiation practice is carried out.
- A Radiation Safety Officer is appointed by the Licensee and is there to advise the Licensee and employees on radiation safety matters associated with the Radiation Practice. It is the RSO that you must contact in the event of an incident.
- It is your obligation as a user to ensure you read and understand the Radiation Safety & Protection Plan. It describes specific procedures for your workplace such as;
  - Safe working rules
  - Emergency Procedures
  - Maintenance Procedures

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User Obligations

- Hold a license issued under the Radiation Safety Act 1999 applicable to the practice *(Analytical X-Ray Unit (hand-held) for chemical analysis)*
- Comply with any conditions imposed on the license
- Read the RSPP and understand their obligations
- Report any contravention of the RSPP
- Understand and be able to implement remediation procedures. Must take reasonable steps to ensure that a person's health and safety are not adversely affected by exposure to radiation because of the way the User carries out the practice.
- Ensuring that any doses received by persons because of carrying out the practice are below the radiation dose limits and are ALARA.
- Undertake training specified in the RSPP

Course Notes p.19

Review the Objectives

RADIATION SAFETY AWARENESS with reference to handheld analyzers

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"That's all Folks!"
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