Radiation Safety & Legislation

Mr. Michael Burke

Radiation Protection Officer (RPO)

Safelab Module 2

23rd Sept 2019

For whom is this relevant?

- Faculty of Science & Health
  - ➢sealed sources (Cs-137, Sr-90, Am-241)
  - ➢X-Ray (Leybold didactic, Niton xrf)
- Faculty of Engineering & Computing
  - ➢X-Ray (Bruker and Bede xrd)

Section A – General Information

- Basic concepts
- Health Effects
- Chernobyl
- Units of Radiation

Section B – Radiation Safety in DCU

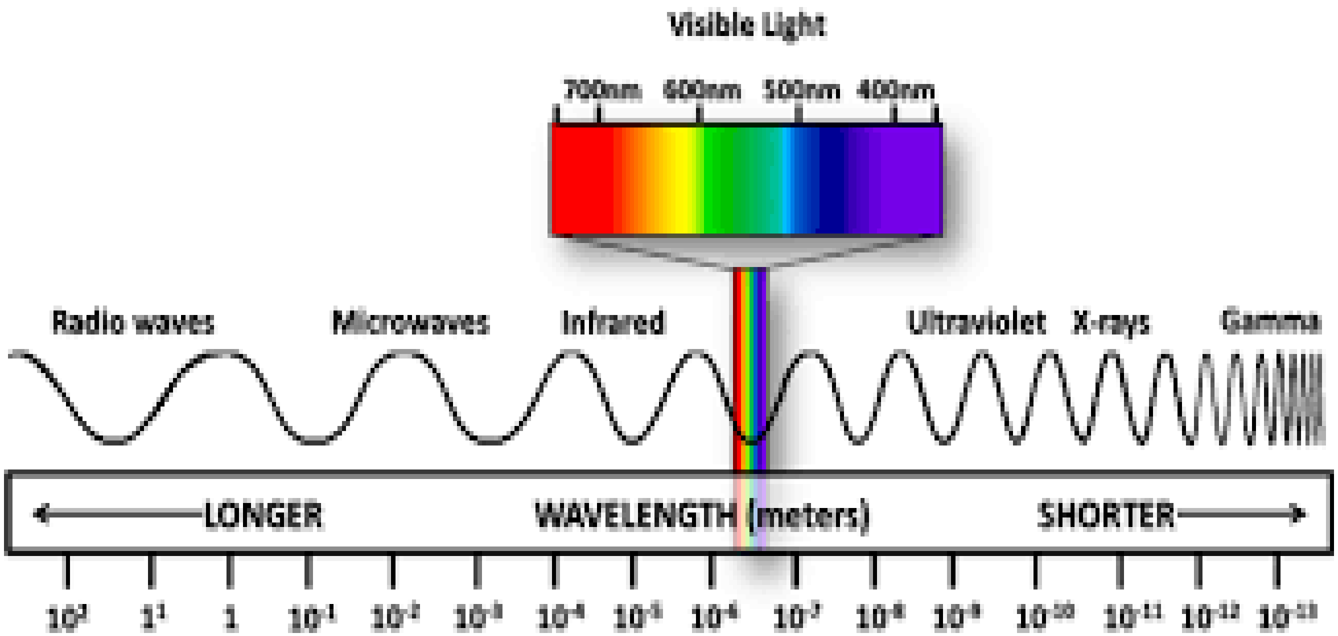
- Legislation
- Role of Radiation Protection Officer
- Radiation Safety Procedures, Risk Assessment
- Acquiring sources
- Dosimetry

Basic Concepts – What is radiation

- Non-ionising: Longer wavelength. Not as harmful in terms of health effects.

- Ionising: creates in matter, electrically charged particles (ions & electrons) – adverse health effects, gene mutation or cancer

Electromagnetic Spectrum



Basic Concepts – What is radiation

Ionising radiation can be artificially produced, e.g. X-Rays, but can also be found naturally in the environment, e.g from soil, rocks, building material, cosmic rays, radon gas

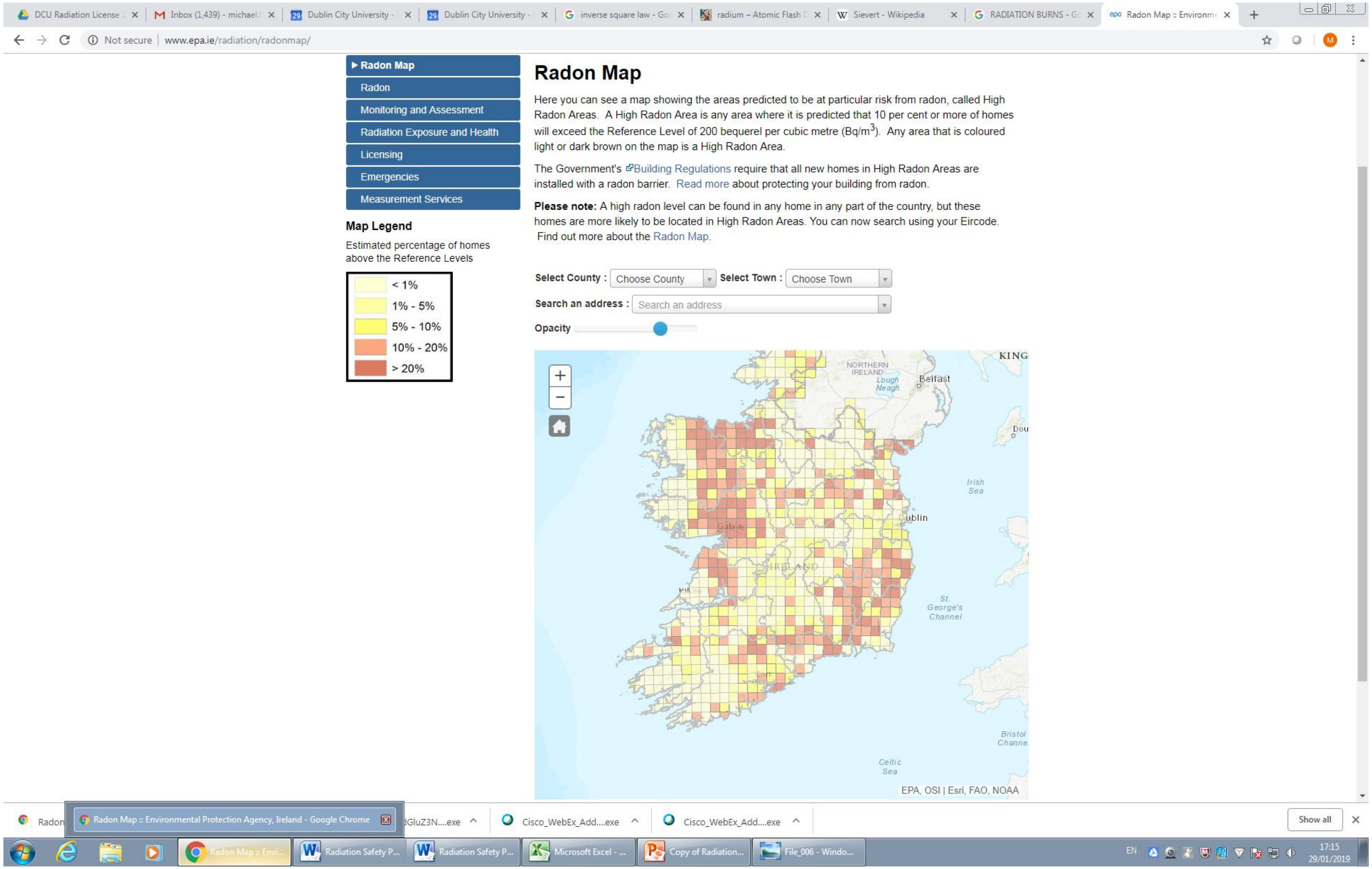
Basic Concepts – What is radiation

Ionizing **radiation**— **does** one main thing to the human body: it weakens and breaks up DNA, either damaging cells enough to **kill** them or causing them to mutate in ways that may eventually lead to cancer

Radon Gas Health Effects

- The greatest health risk from radiation in Ireland is caused by radon
- It accounts for more than half of the total radiation dose rec'd by the Irish population
- A known carcinogen
- Up to <u>250</u> cases of lung cancer in Ireland every year can be linked to radon.

Radon Map of Ireland

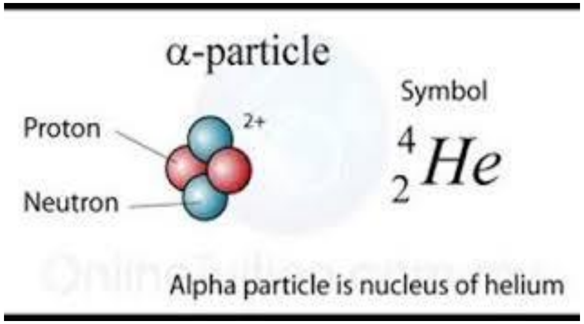


Basic Concepts – Types of Radiation

There are several different ways in which an unstable nucleus can emit its energy and produce radiation. Can be one of five main types

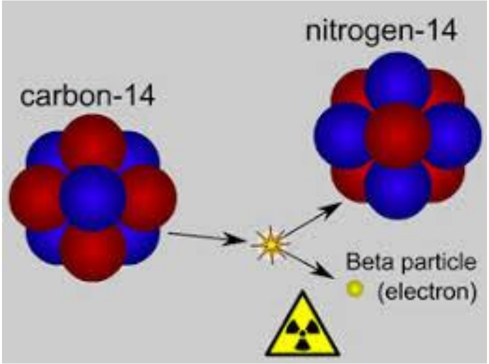
1. Alpha (α)
2. Beta (β)
3. Gamma (γ)
4. X-Rays
5. Neutrons

Basic Concepts – Types of Radiation (Alpha)



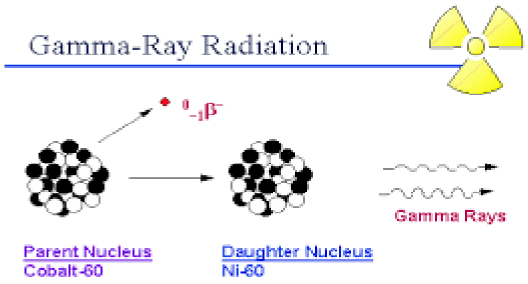
- Alpha particles have 2 protons & 2 neutrons
- Very energetic – interact with matter
- Not an external hazard – stopped by air, paper
- Significant internal hazard

Basic Concepts – Types of Radiation (Beta)



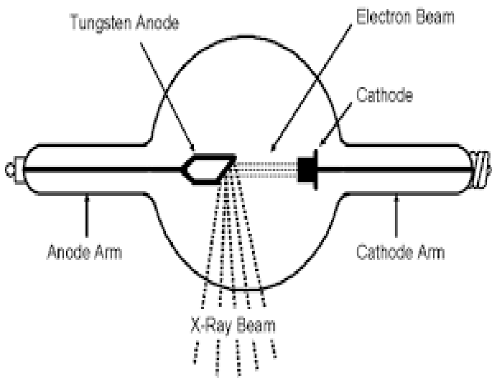
- Beta particles are high speed –ve charged electrons
- External & internal hazard
- Range – several metres in air
- Stopped by approx. 1cm perspex

Basic Concepts – Types of Radiation (Gamma)



- Gamma rays are high energy electromagnetic radiation
- Very penetrating – significant external hazard
- Travel up to several hundred metres in air
- Require lead or concrete for shielding

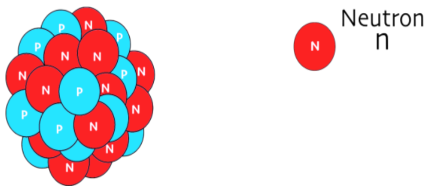
Basic Concepts – Types of Radiation (X-Rays)



- Similar to gamma rays
- Generated by X-Ray equipment
- High speed electrons hit a solid target, X-rays produced
- X-ray equipment can be switched off, whereas gamma sources must decay naturally

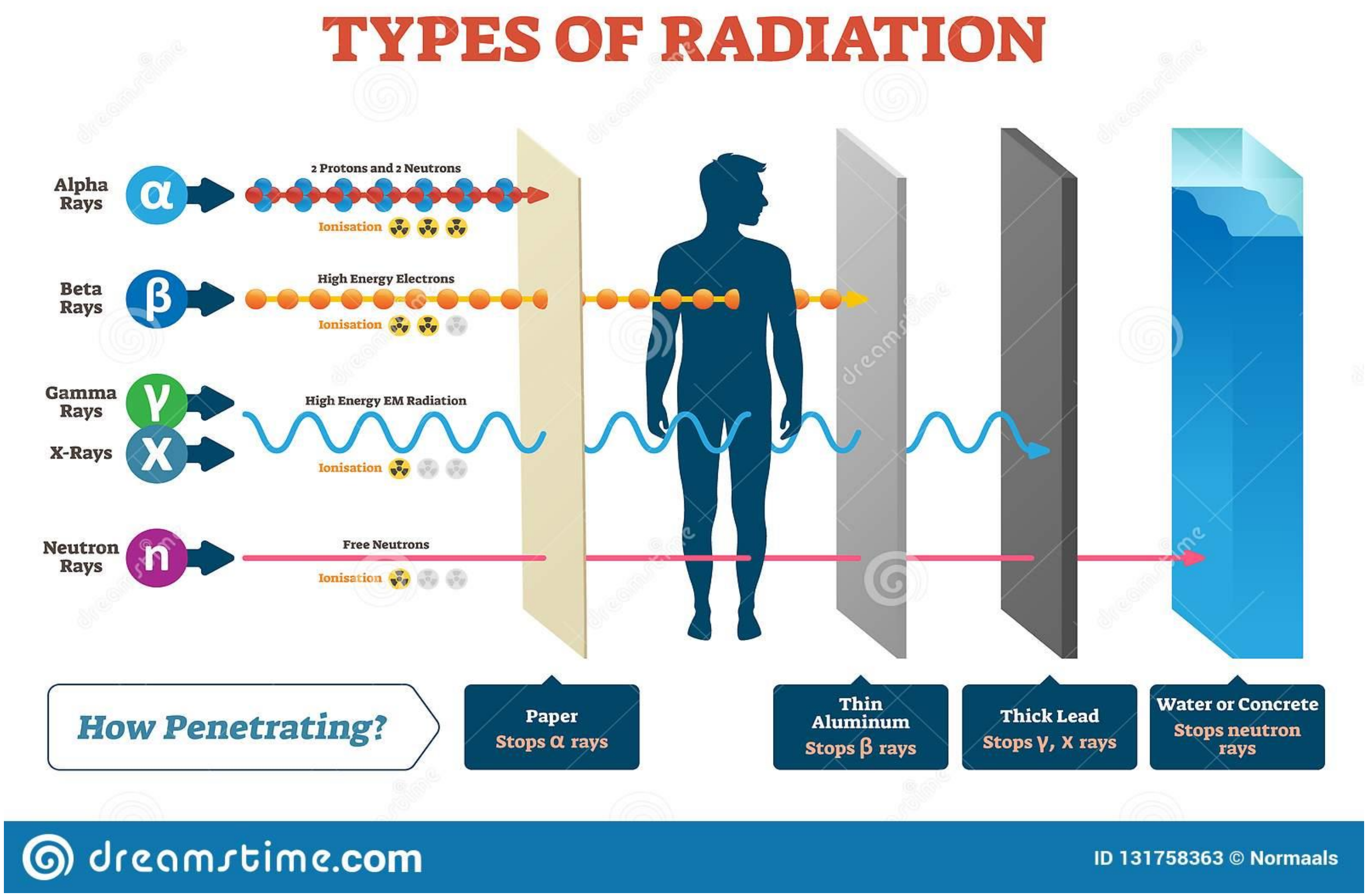
Basic Concepts – Types of Radiation (Neutrons)

- Neutron radiation consists of a free neutron, usually emitted as a result of spontaneous or induced nuclear fission
- Can travel thousands of meters in air



- They are stopped if blocked by a hydrogen-rich material - concrete or water
- Only type of radiation that is able to turn other materials radioactive

Properties of α, β, γ,n radiation



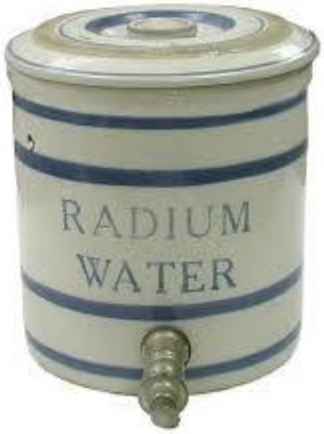
Alpha (α) radiation poisoning

- Mr Alexander Litvinenko in London 2006
- Met with Russian security personnel and had tea which contained Polonium 210.
- Within 3 weeks, suffered complete organ failure and died.
- The high amt of ^{210}Po resulted in rapid cell death and multiple organ failure
- 250,000 times more toxic than hydrogen cyanide

Health Effects

- When radiation was first discovered, its danger to health was not known
- Many thought this energy would have health benefits
- Radioactive consumer products came on the market in the 1920s and 1930s

Health Effects



Health Effects - The “Radium” Girls

- In the 1920s, young women were employed to paint clock dials with luminous paint containing radium

- To get a fine point on the brush they licked the bristles and ingested radium
- They suffered from cancers as a result: α and γ radiation
- Resulted in a change in US Labour Laws

Chernobyl Reactor explosion 1986

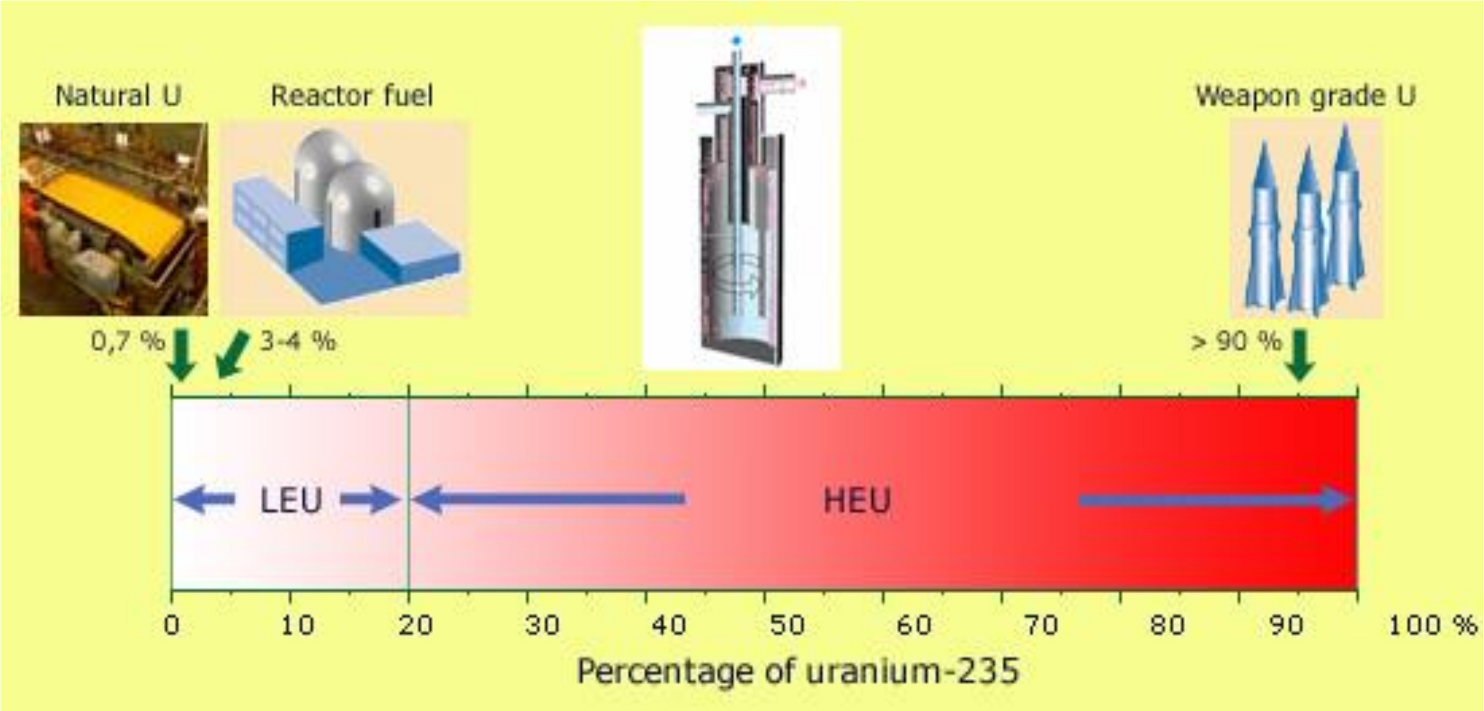
- The **Chernobyl** explosion put 400 times more radioactive material into the Earth's atmosphere than the atomic bomb dropped on **Hiroshima**
- 300 Sv/h shortly after the explosion in vicinity of the reactor core (2.6×10^9 greater than permissible dose)
- Main contaminants in exclusion zone: Cs-137, Sr-90 and I-131
- Areas around the **Chernobyl** nuclear power plant will remain uninhabitable for at least 20,000 years

Chernobyl v's Atomic bombs

Why is Hiroshima & Nagasaki habitable but not Chernobyl

- Little Boy and Fat Man were detonated in mid-air, radioactive debris dispersed by the mushroom cloud
- Reactor number four melted down at ground level, the soil underwent neutron activation
- About two pounds of Little Boy's uranium reacted, about two pounds Fat Man's plutonium underwent nuclear fission
- At Chernobyl, at least seven *tons* of nuclear fuel escaped into the atmosphere

Uranium-235



The boundary between the uranium meant for civilian uses (low-enriched uranium) and that uranium meant for military use (highly-enriched uranium) is generally fixed at 20%.

Radiation Units

Japan's unfolding nuclear disaster has introduced the confusing practice of measuring radiation exposure

According to some stories, the water nearby the No. 2 Fukushima reactor has a radioactivity level of 1,000 millisieverts/hour

But other articles describe radiation levels in terms of millirem/year

And a few sources have referred to exposure in terms of millirad or nanogray/ hour. Why don't all radiation experts just use the same unit?

Radiation Units

- When radiation is first emanating from its source, physicists refer to the rate of emission in **Becquerels** (rate of emission)
- Once the radiation has cleared the source, we need a new set of units. Ambient radiation levels are expressed in **roentgens** (customary) or **coulombs per kilogram** (SI)
- If the radiation leaves the air and enters a person, animal, or object, the units switch again. The raw amount of radiation that an object absorbs is expressed in either ***rad*** (customary) or **gray** (SI)
- **Sieverts** and **rems** provide a measure of the potential harm caused by radiation in a sample of living tissue

Radiation Units

- Different types of radiation affect the body in different ways - alpha particles <u>20</u> times more dangerous to human tissue than gamma rays at the same dosage level

- A blast of radiation to the spleen will cause more damage than the same dose to the brain - splenic tissue divides and multiplies much faster

Basic conversions

- 1 gray (Gy) = 100 rad
  1 rad = 10 milligray (mGy)
  1 sievert (Sv) = 1,000 millisieverts (mSv)

- 1 sievert = 100 rem
  1 becquerel (Bq) = 1 count per second (cps)
  1 curie = 37,000,000,000 becquerel = 37 Gigabecquerels (GBq)

- For x-rays and gamma rays, 1 rad = 1 rem = 10 mSv
  For neutrons, 1 rad = 5 to 20 rem (depending on energy level) = 50-200 mSv
  For alpha radiation,1 rad = 20 rem = 200 mSv

Units used in ionising radiation

- Becquerel (Bq). 1 Bq = 1 disintegration/sec. A measure of activity
- Sievert (Sv). Dose received by human body from different types of radiation. Normally expressed in mSv
- Dose rate is mSv/h

Section B: Radiation Safety In DCU

- Legislation
- Role of Radiation Protection Officer
- Radiation Safety Procedures, Risk Assessment
- Principles of Protection
- Acquiring sources
- Dosimetry
- Emergency Procedures

Relevant Legislation - SI 30 of 2019 & SI 256 of 2018

Non-medical use of radiation sources:

Radiological Protection Act 1991, (ionising radiation) Regulations 2019 - S.I. No. 30 of 2019. Enacted 8th Feb'19.

Regulating authority - EPA

Medical exposure to ionising radiation: S.I. No. 256 of 2018

European union (basic safety standards for protection against dangers arising from medical exposure to ionising radiation) regulations.

Regulating authorities – EPA/ HIQA

ORP-EPA regulatory authority

- ORP-EPA: Office of Radiological Protection – Environmental Protection Agency
- RPO: Radiation Protection Officer – Assists in the preparation & amendment of radiation safety procedures & ensures relevant regulations are upheld (Mr. Michael Burke)
- RPA: Radiation Protection Adviser - External consultant with expertise in radiation protection (Dr. Elaine Doorly).

Role of Radiation Protection Officer

- Provide advice and comments on work plans
- Maintain adequate records of all radiation sources
- Provide new workers with an introduction to procedures
- DCU point of contact with the ORP-EPA
- Carry out periodic audits and measurements
- Liaise with the radiation protection adviser

Radiation License L0169-04

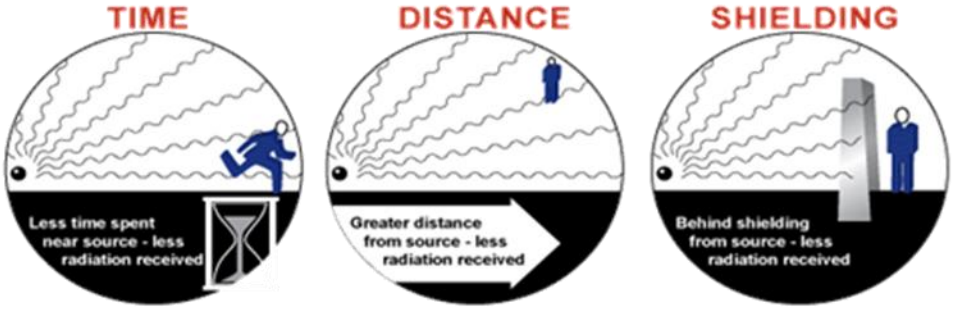
Sealed Sources e.g. Am-241, Ba-133, Cd-109, Cs-137, Co-57, Co-60, Ni-63, Ra-226, Na-22, Sr-90	**School of Physical Sciences** NG-13 (lead store) NG-24
Unsealed Sources e.g. I-125, C-14, H-3, Ca-45, P-32	**School of Biotechnology** X-175. No unsealed sources in use
Irradiating Equipment Niton XL 900 XRF Leybold didactic Rontgengerat X-Ray Oxford Gemini XRD (custody only) Bruker D8 XRD (custody only) Bede D1 XRD Stratos Densitometer (custody only)	NRF (GAG-02c) School of Physical Sciences (NG-24) School of Chemical Sciences (XB-12) Research & Engineering (S-124) Research & Engineering (NG11a) DCU Exwell Medical Centre

Radiation Sources in DCU

- X-Ray Equipment

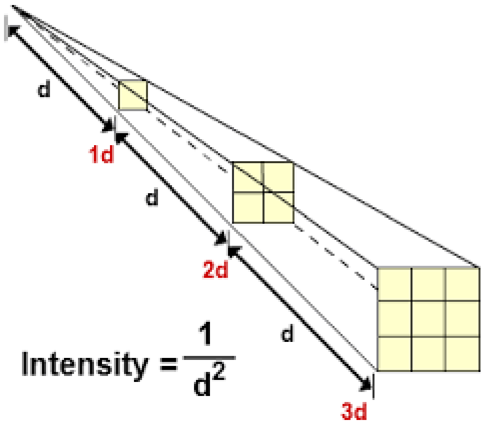
- Sealed Sources
- No Unsealed Sources currently in use

Three Principles of Protection



- Time - Limit time spent beside source
- Distance – Maximise distance from source
- Shielding – Shield the source with appropriate material, e.g. lead, perspex

Inverse Square Law – External radiation



- Double you distance and quarter your dose
- Dose reduces by $1/d^2$
- Example: dose rate at 1m = 20mSv/hr therefore; dose rate at 2m = 20/4 = 5mSv/hr

ALARA Principle

All radiation should be kept as low as is reasonably achievable

- Keep time to minimum *Dose ~ time*
- Use forceps for sealed sources
- Keep distance to a maximum *Inverse square law*
- Use adequate shielding
- Restrict access

Calculating Dose Rate from known Activity

- From MSDS, Cs-137 has a dose rate of 0.103 mSv/h/GBq at 1 metre
- If we have a Cs-137 source of 333kBq, the dose rate = $0.103/10^6 \times 333$

  = 3.42×10^{-5} mSv/h
- Exposure time req'd to receive 1mSv = 3.34 yrs
- 1mSv/yr is the Annual Limit for Public

Example of sealed sources used in DCU

Radionuclide	Activity kBq	Ext dose @1m mSv/h	Dose if source ingested mSv	Dose if source inhaled mSv	1/2 life	Principal Emissions
Ni 63	370,000	2.4×10^{-6}	57	195	96 yrs	Beta
Ra 226	185	5.6×10^{-7}	50	168	1600 yrs	Alpha / gamma
Ba 133	37	4.5×10^{-6}	0.025	0.071	10.51 yrs	Gamma / Beta
Cd 109	37	1.7×10^{-6}	0.074	0.148	453 days	Gamma

Biological Effects – Dose relationship

• Background Ireland	3.9mSv/y
• Annual Limit (Rad worker)	20mSv/y
• Annual Limit (Public)	1mSv/y
• Return flight to Tenerife	0.04mSv
• Chest X-Ray	0.05mSv
• Chromosome change	>100mSv
• Blood count change	>1000mSv

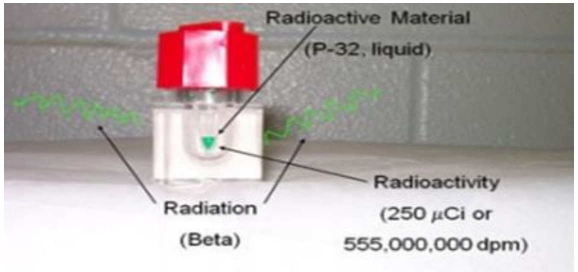
- The greatest health risk from radiation in Ireland is caused by radon

Unsealed Sources – Radioactive tracers

- If you plan to work with P-32, S-35, I-125, C-14 and 3-H, *you must consult with RPO*
- Significant training required before work can commence
- Currently no Unsealed Sources approved on DCU License
- The major hazard is ingestion/inhalation

Unsealed Sources – Radioactive tracers

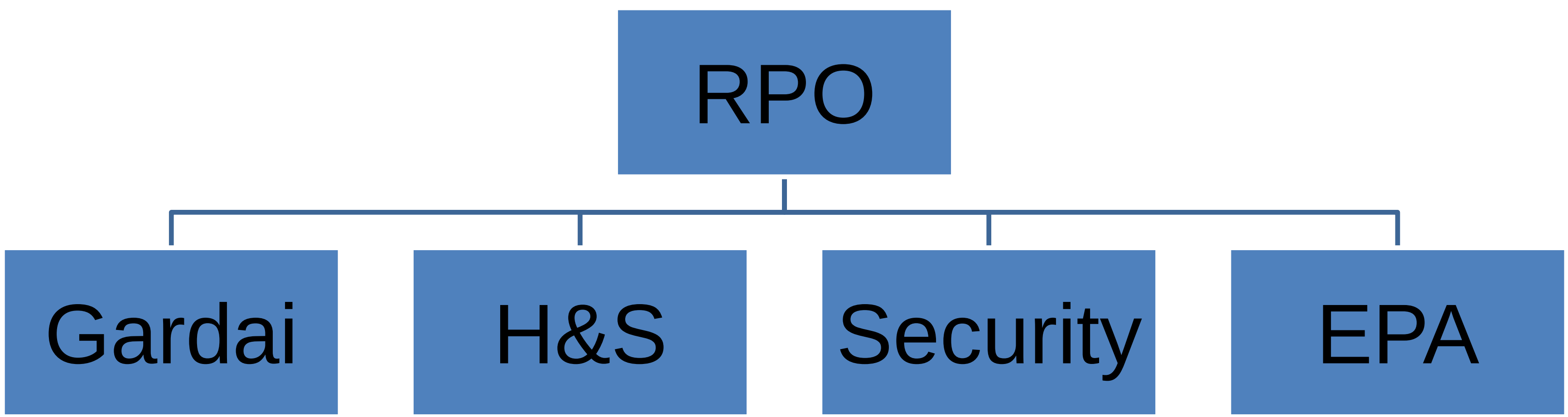
- Registration Form
- ***Conduct*** risk assessment
- ***Control*** quantities of materials



- ***Contain*** materials
- ***Confirm*** dose rates and lack of contamination

- The Laboratory
- Personal Behaviour
- Wear TLD when working with P-32 and I -125
- Contamination Monitoring
- Receiving & Storing
- Radioactive waste
- Housekeeping
  - Registration Form
  - Isotope record form
  - Users' Log Book
  - Record all disposal in Disposal Log book

Theft/ Loss of a source



Damage during transport

- Monitor package for surface contamination
- Obtain contact details for distributor
- Contact distributor
- Replace in emergency container box
- Seal, label and arrange for replacement
- RPO to report

Dosimetry Service

- Service provided by Landauer Europe
- Area monitoring in place for all x-ray equip
- Checked monthly & results recorded and monitored
- Thermoluminescent dosimeter badges (TLD) worn for work with unsealed sources
- Based on risk assessment

Pregnant Workers

- **Pregnant workers** should formally notify their supervisor and the RPO when they become pregnant or their intention to become pregnant so that dose reduction steps can be taken
- The RPO will determine what steps are necessary to maintain all doses to the embryo/foetus below allowable limits
- Appropriate personnel monitoring equipment must be provided to individuals who have declared a pregnancy or planned pregnancy
- The radiation dose to the foetus not exceeds 1mSv during remainder of pregnancy
- Exposure during the first trimester is the most hazardous
- Monthly TLD monitoring will be established during the pregnancy period. Exposures potential must be below 1mSv/ 9months.

Source Reduction

DCU supports the principle of source reduction and will dispose of unused sources in accordance with current legislative requirements

Emergency Equipment

For unsealed/ sealed sources

- Contamination monitors (Mini 900 ratemeter)
- Latex gloves, white coat, perspex glasses
- Perspex screens, warning notices
- Long handled forceps
- Storage container (perspex,lead,concrete)
- Equipment manuals
- Bags of lead shot, lead sheet
- Fire blankets, extinguishers

- New form DCU Risk Assessment template to be used for new sources
- Radiation Safety Procedures (RSP) updated annually and each time a new source added or a source removed
- RSP provided to users and <u>recorded</u>
- Dosimetry service where applicable
- Training records maintained

- Copy of Licence on public display
- Copy of RSP available in hard copy in the lab
- Annual checks by RPO and RPO
- SOPs required for all equipment and made available

License request for X-Ray Equipment

Applies to irradiating equipment operating >30kV

An application for the addition of an X-Ray source must be accompanied by the following documents and submitted to the ORP-EPA by the RPO in advance of the acquisition of the source:

- Risk Assessment & update Radiation Safety Procedures
- Plan of the facility
- The X-Ray source will then be licensed with the licensing restriction “custody and commissioning purposes”
- Restriction removed once a copy of Installation Report is submitted and approved by the ORP-EPA

License request for Sealed Source

- Risk Assessment
- Radiation Safety Procedures updated
- Plan of the facility
- Take back agreement with supplier
- Valid wipe test certificate from supplier
- Council Regulation (Euratom) No.1493/93 completed & stamped by ORP-EPA
- Application to the ORP-EPA by RPO
- Approval from ORP-EPA

Radiation Monitoring Equip

Two monitors maintained by RPO:

- Thermo Scientific Ratemeter – contamination (counts/second)
- RadEye B20 – dose mSv/hr
- Serviced annually

Shared Drive