Radioactivity, irradiation: Hazards, accidents & occupational dose limits

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Topics

Radioactivity

- Definition/concept
- Historical overview
- Units

Topics

- **SOURCES OF RADIATION**
- Natural/ background
- Man-made sources – x-rays, radioactive materials (sealed/unsealed)
- Properties of radiation emissions - γ, β, α, X-radiation
- Biological effects of ionising radiation

Topics

- **USES OF IR SOURCES**
- Schools
- Research (Agric, archaeology etc)
- Energy
- Oil exploration
- Hydrology
- Medical – diagnostic, therapeutic etc

Topics

- **RADIATION PROTECTION**
- Concept & need for RP
- Principles of radiation protection
- Methods of dose reduction

Topics

- **DOSE LIMITS**
- Concept
- Public
- Patients
- Radiation workers

Topics

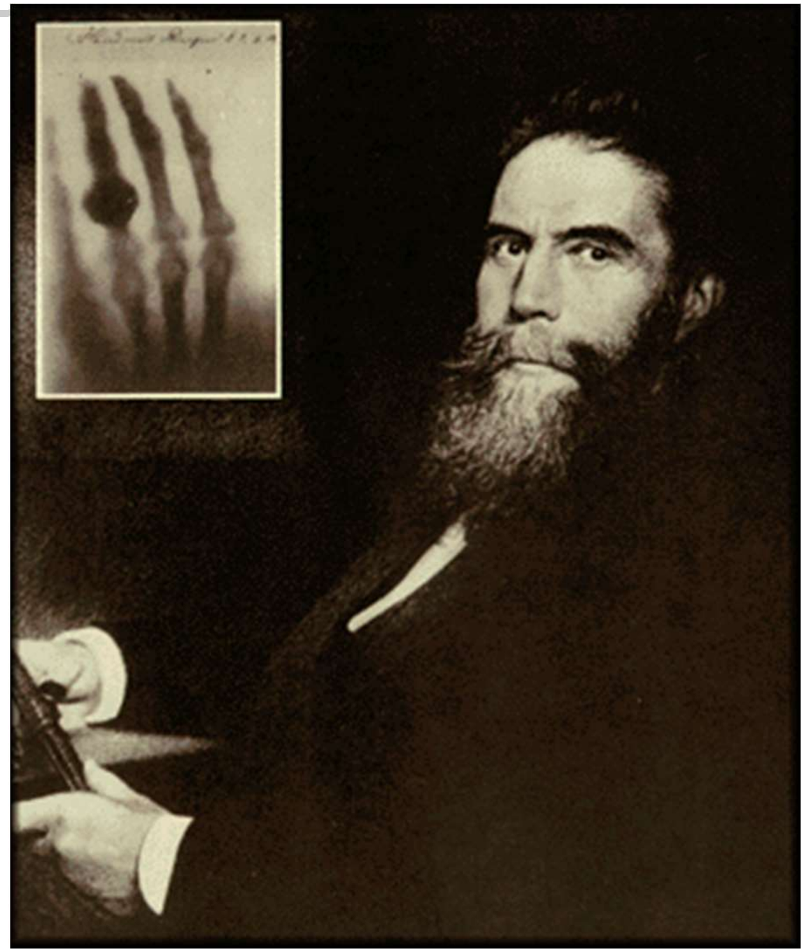
- **ACCIDENTAL EXPOSURE**
- Nuclear medicine - cite few examples
- Other radiological accidents - mention

Topics

- **LEGISLATION**
- The IAEA
- The Radiation Protection Act – Cap 243 – laws of Kenya
- Web links: www.iaea.org, www.icrp.org, www.icru.org, www.irpa.org and others

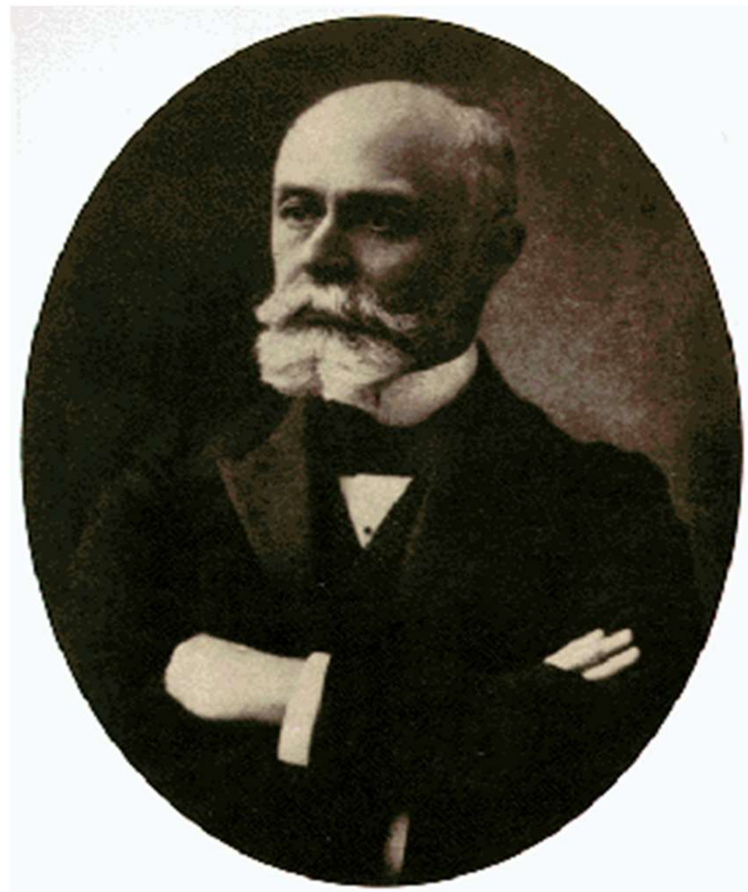
Radioactivity - History

- ***Wilhelm Conrad Roentgen (1845-1923)***
- *Inset photo: Radiograph of Frau Rontgen's hand*
- discovered X rays, a momentous event that instantly revolutionized the field of physics and medicine
- Received the 1st Nobel Prize in Physics 1901



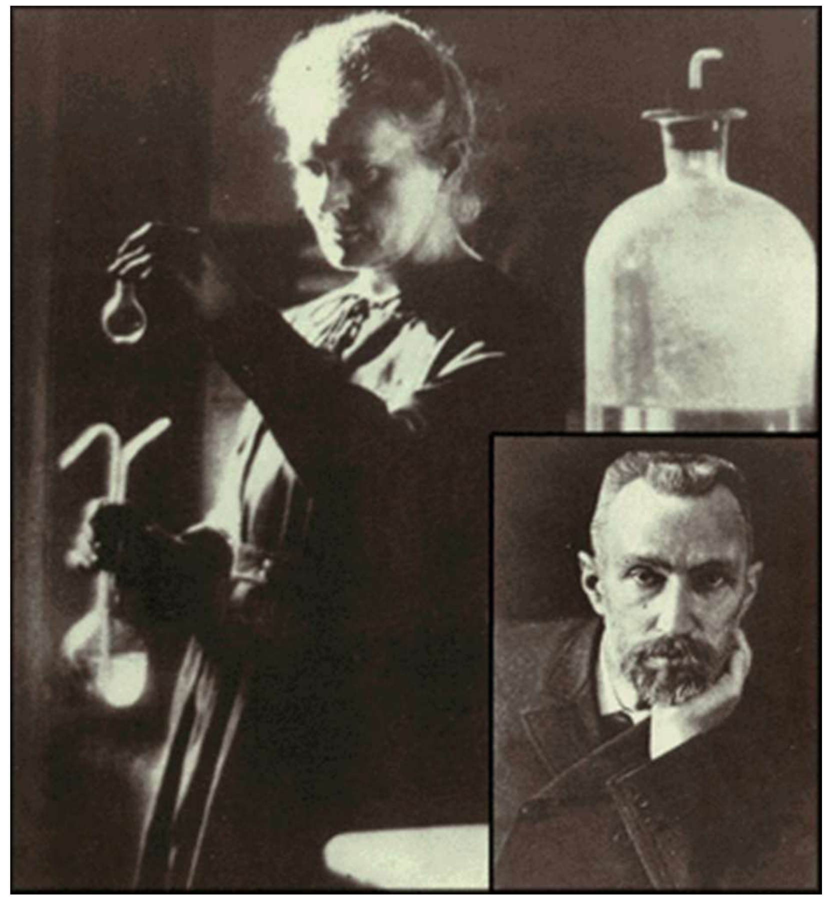
Radioactivity – History.....

- **Antoine Henri Becquerel (1852-1908)**
- Discovered radioactivity
- Nobel Prize for physics 1903



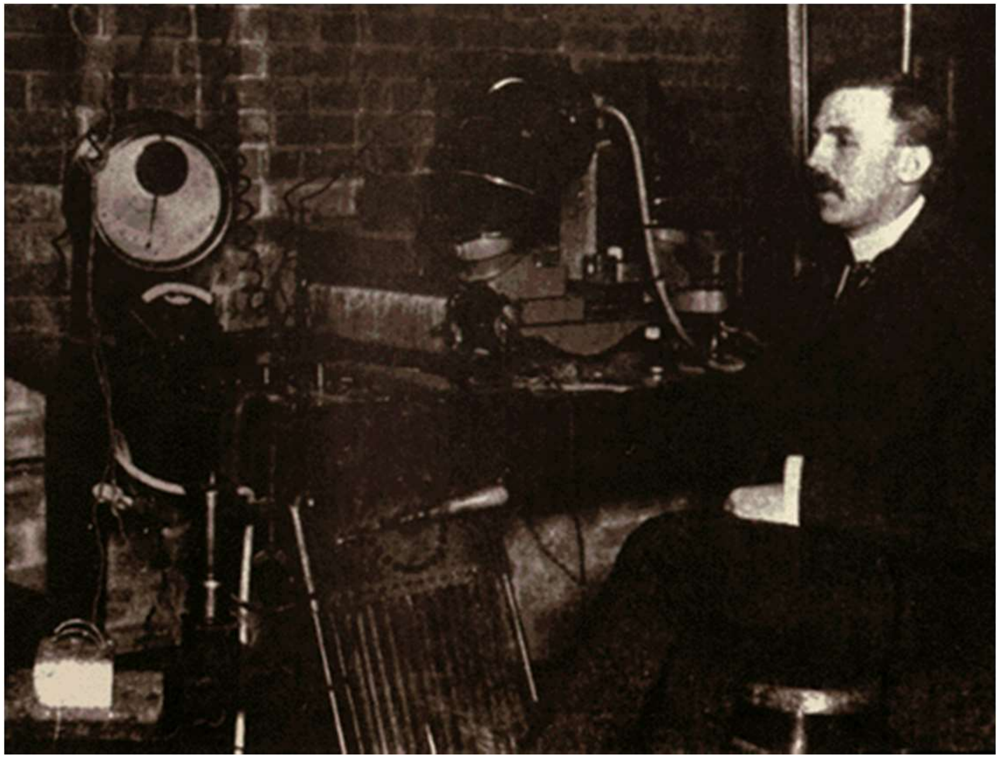
Radioactivity – History…..

- **Pierre Curie(1859-1906)**
- **Marie Curie (1867-1934)**
- Nobel prize in Physics 1903
- Later Nobel Prize in chemistry
- Discovered Radium and Polonium
- Died as a result of overwork & extensive radiation exposure



Radioactivity – History…..

- **Ernest Rutherford (1871-1937)**
- Father of nuclear physics – developed concept of atom
- Characterised proton, alpha & beta particles



Radioactivity – History…..

- Irène Curie and Frédéric Joliot
- Discovered artificial radioactivity
- Discovered phosphorus – 30 & received Nobel Prize in Chemistry
- Formed basis for isotope production

Radioactivity

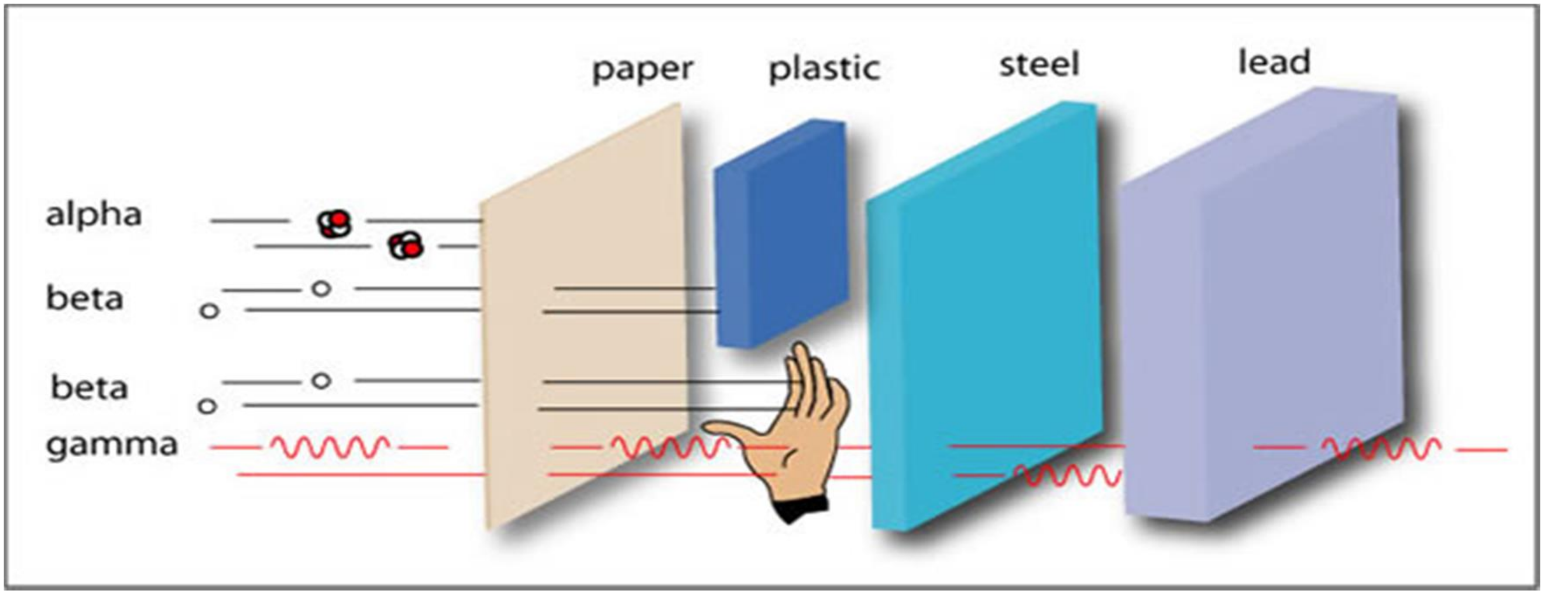
- Radioactivity is the property of some unstable atoms (radionuclides) to spontaneously emit nuclear radiation, usually alpha- or beta- particles, often accompanied by gamma-rays.
- This radiation is emitted when the nucleus undergoes radioactive decay and is converted into a different isotope which may, according to its number of neutrons and protons, be either radioactive (unstable) or stable (non-radioactive). This **"daughter"** nucleus will usually be of a different chemical element to the original isotope

What causes atoms to be radioactive?

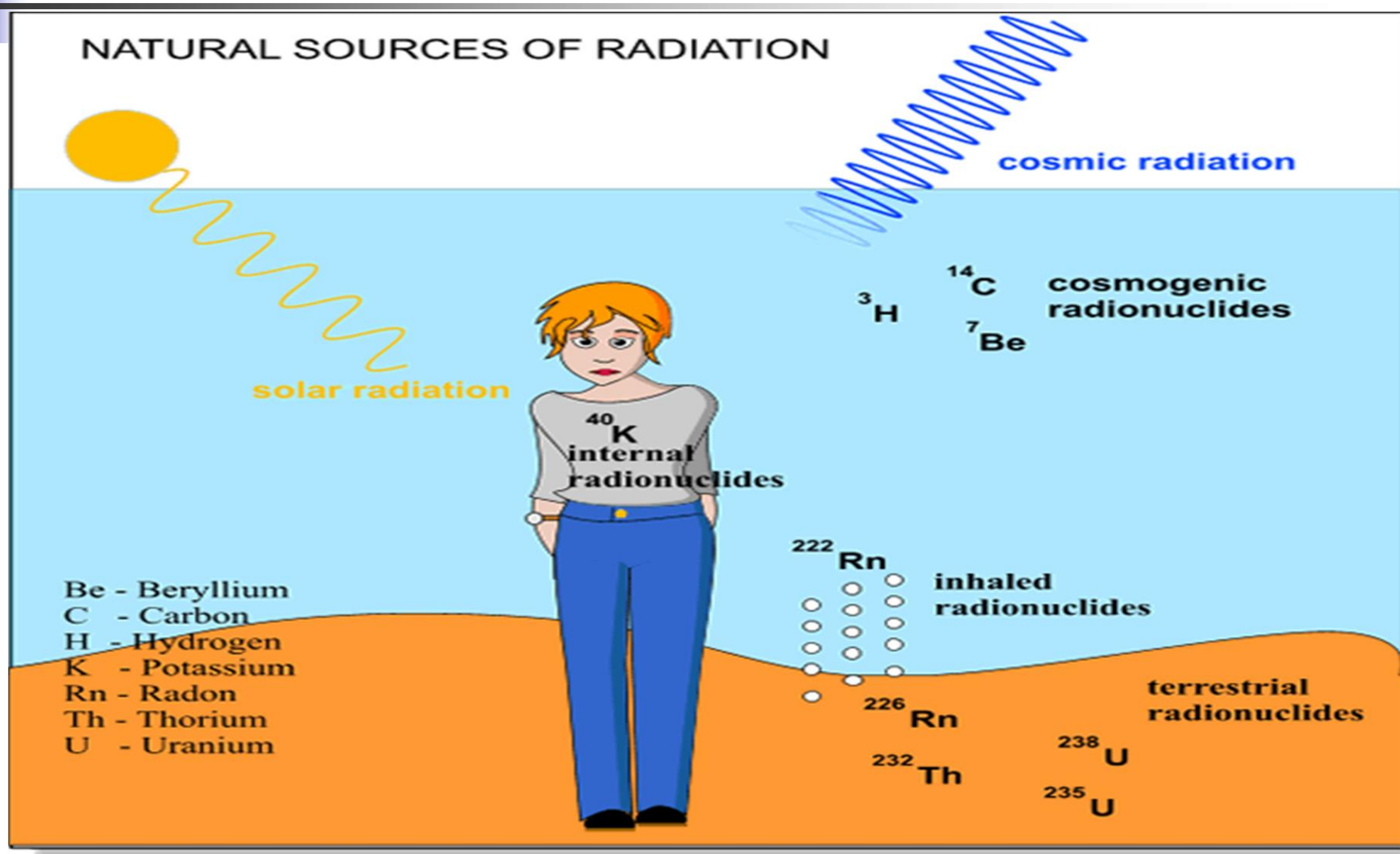
- Atoms found in nature are either stable or unstable. An atom is stable if the forces among the particles that makeup the nucleus are balanced. An atom is unstable (radioactive) if these forces are unbalanced; if the nucleus has an excess of internal energy. Instability of an atom's nucleus may result from an excess of either neutrons or protons.

Types of Ionizing Radiation

- Alpha (**α**) particles
- Beta (**β**) Particles
- Gamma (**γ**)rays

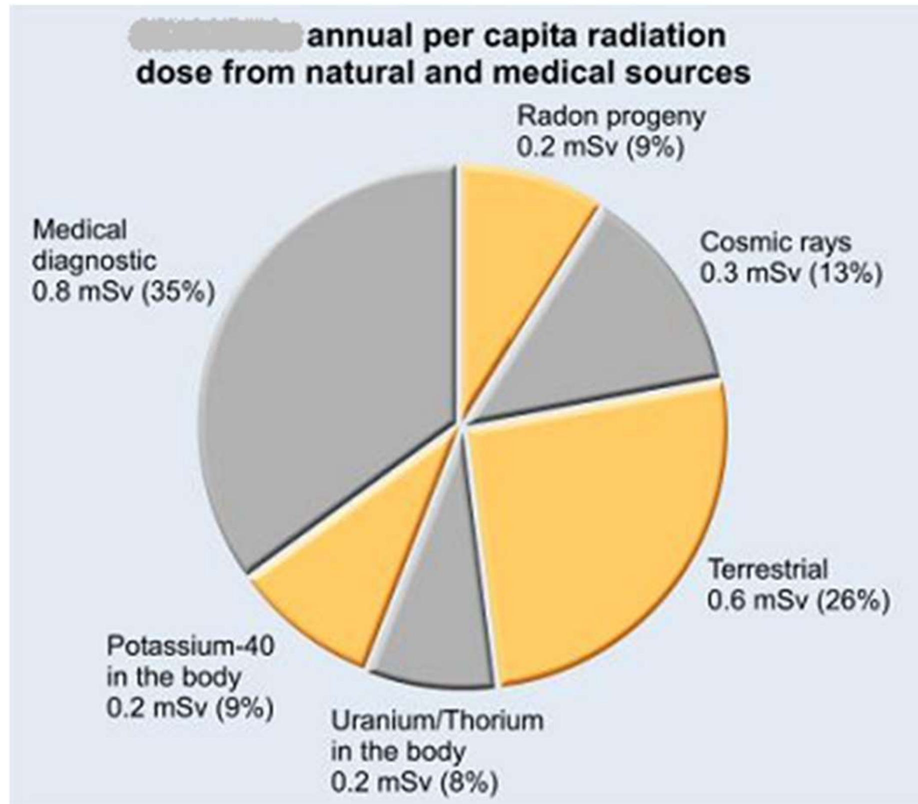


Natural Radiation (NORMs)



Background & Medical radiation

- In the world the dosage rate from background radiation, the sum of all natural radiation, is about 2 millisieverts per year.



Radiation From Food

Radiation - We live with

Food	Radioactive levels (Bq/kg)				
	Daily intake (g/d)	Ra-226	Th-228	Pb-210	K-40
Rice	150	0.126	0.267	0.133	62.4
Wheat	270	0.296	0.270	0.133	142.2
Pulses	60	0.233	0.093	0.115	397.0
Other Vegetables	70	0.126	0.167	--	135.2
Leafy Vegetables	15	0.267	0.326	--	89.1
Milk	90	--	--	--	38.1
Composite Diet	1370	0.067	0.089	0.063	65.0

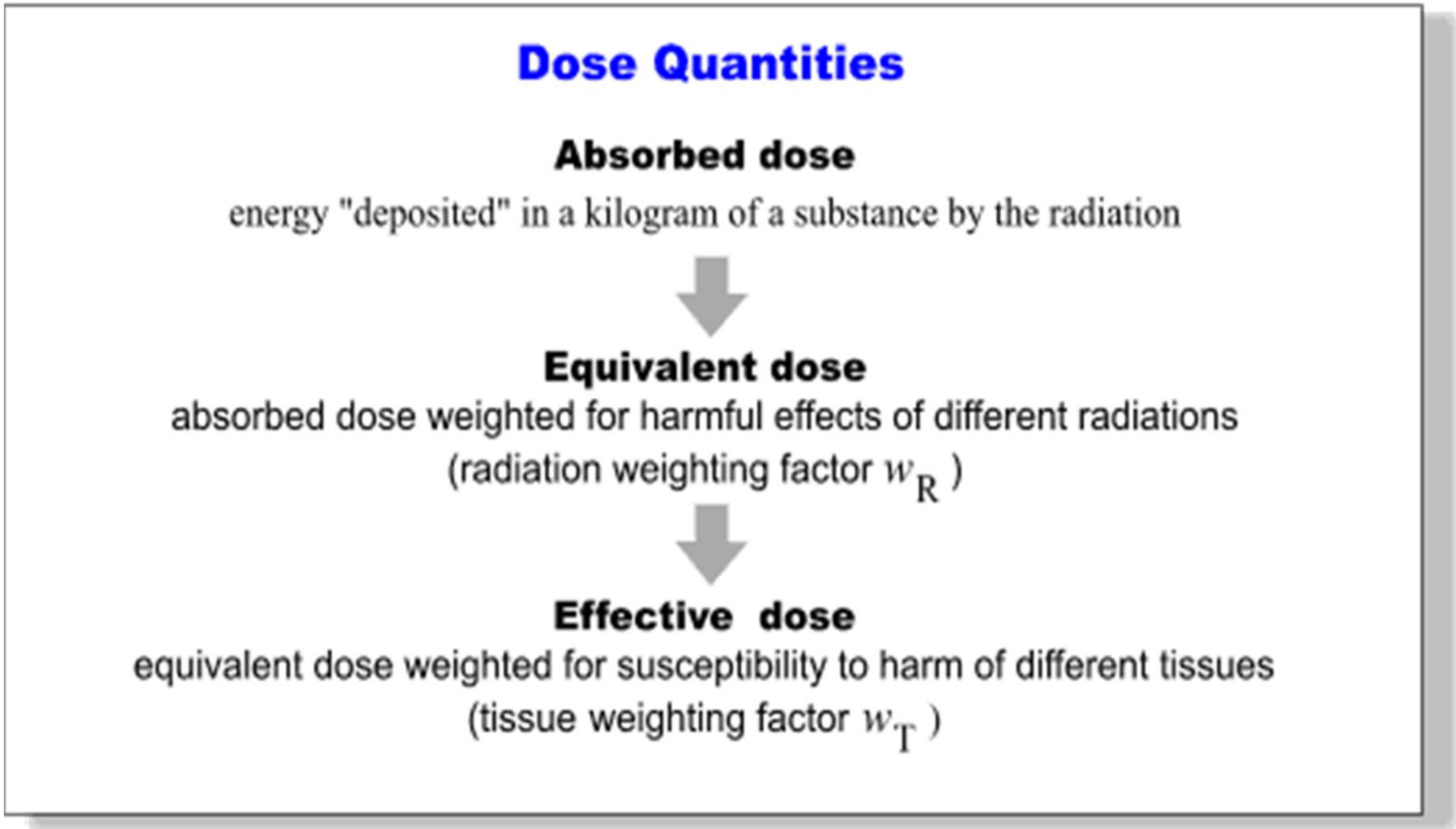
Dose equivalent=0.315 mSv/yr
Total dose from Natural sources = 1.0 to 3.0 mSv/yr

IAEA

Units for Measuring Radiation

- We measure two general phenomena. **"activity"** and **"exposure".**
- Activity - **how much radiation is coming out of something**, whether it's particles or waves. **(Becquerel-Bq)**
- Exposure - **the effect of radiation on substances that absorb it**.

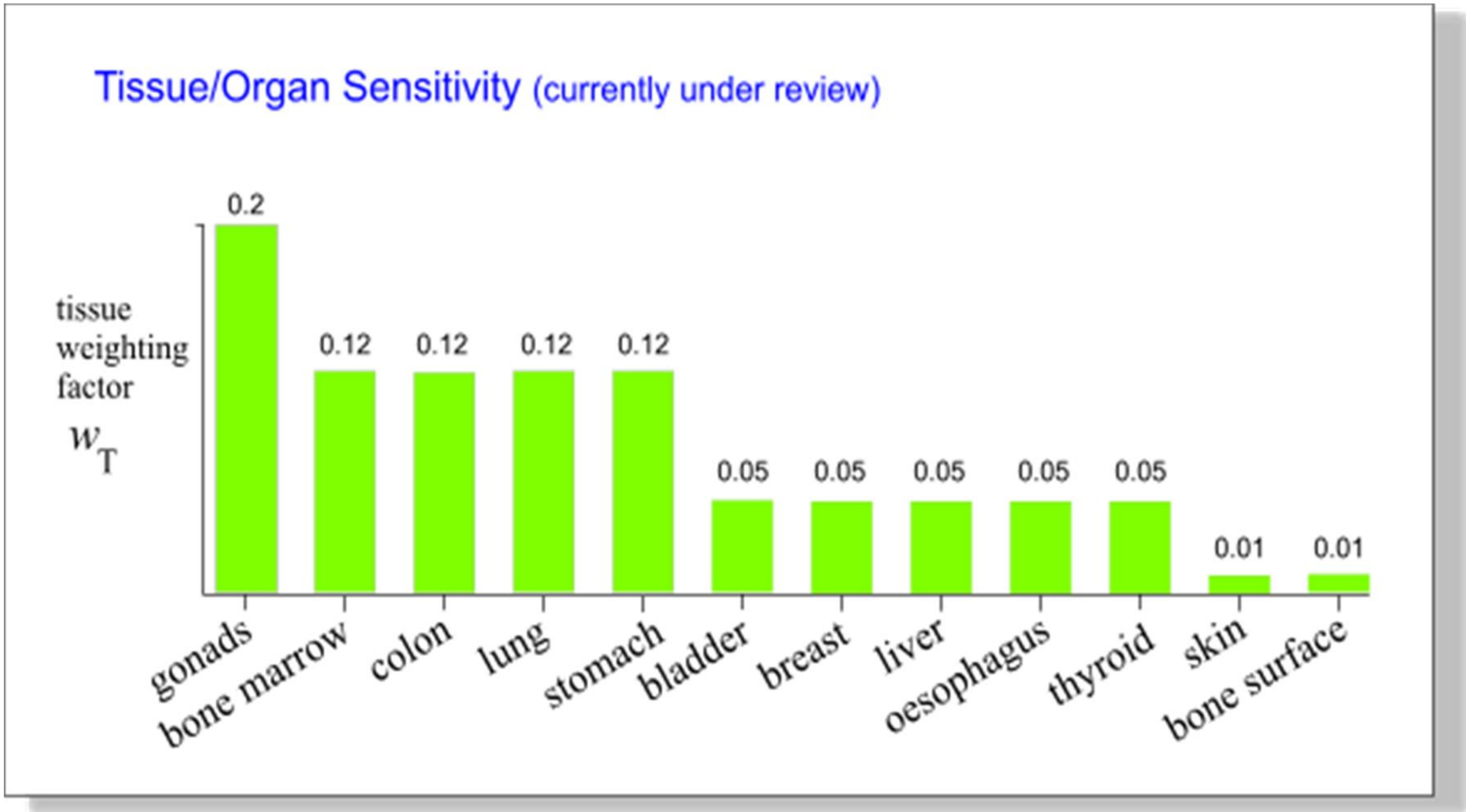
Radiation Doses



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).

Tissue Weighting Factors W_T



Limits of exposure to radiation

- **Radiation workers** - 20 mSv averaged over five years
- **General public** - 1 mSv

(ICRP - International Commission on Radiological Protection)

Health effects of Ionizing Radiation

- Radiation may affect living things by affecting the cells . Radiation effects on a cell are **random /probabilistic**
- the same type and amount of radiation could strike the same cell many times and have a different effect, including no effect, each time.
- If a significant number of cells are affected, the organism may be damaged or even die.

Radiation Effects on a Cell

When a cell absorbs radiation, there are **four** possible effects on the cell

- suffer enough damage to cause loss of proper function
- lose its ability to reproduce
- the cell's genetic code (i.e., the DNA) may be damaged such that future copies of the cell are altered, which may result in cancerous growth
- the absorption of radiation by a cell may have no adverse effect.

Threshold effects and non-threshold effects

- **Threshold effects** appear after a certain level of radiation exposure is reached and enough cells have been damaged to make the effect apparent
- **Non-threshold effects** can occur at lower levels of radiation exposure.
- Two approaches are used to study their various biological effects: **epidemiology** and **experimentation on living cells**.

Kenya Bureau of Standards

Threshold effects and non-threshold effects...

Dose range	Effect
0 to 250 mGray	no biological or medical effect. This is the domain of low doses
250 to 1000 mGray	some nausea along with a slight decrease in the number of white blood cells
1000 to 2500 mGray	vomiting, change in the blood count, but satisfactory recovery or complete cure assured
2500 to 5000 mGray	Serious; hospitalisation mandatory; 5,000 mSv received all at once is lethal for one out of two people
> 5000 mGray	death is almost certain

Delayed Effects of Radiation

- Classification:
- SOMATIC: they affect the health of the irradiated person. They are mainly different kinds of cancer (leukemia is the most common, with a delay period of 2-5 years, but also colon, lung, stomach cancer…)
- GENETIC: they affect the health of the offspring of the irradiated person. They are mutations that cause malformation of any kind (such as mongolism)

Uses of Radiation Sources

- Going back in time: dating
- Isotopic labelling in biology and medicine
- Medical Diagnosis
- Radiotherapy & Nuclear medicine
- Nuclear energy & Production of electricity
- Sterilisation
- Protecting works of art
- Production of materials
- Industrial X or γ- radiography
- Leakage detectors and level gauges Fire/smoke detectors
- Research (e.g XRDF, MCA etc**)**

Nuclear medicine

- Philosophy: Efficacy, safety
- Diagnosis – mainly imaging
- Therapy – radiopharmaceutical administration (e.g. Iodine – 131 for thyroid cure)

Examples of Sources used in Nuclear medicine ….

Nuclide **Type of Examination**

- $^{99}Tc^{m}$ - Bone imaging
  - - Bone marrow imaging
  - - Brain imaging
  - - Cerebral blood flow
  - - Thyroid imaging
  - - Lung ventilation & perfusion imaging
  - - Liver and spleen imaging
  - - Cardiovascular imaging
  - - Gastro-intestinal imaging
  - - Renal imaging

Examples of Sources used in Nuclear medicine ….

Nuclide	Type of Examination
▪ ^{131}I	- Thyroid imaging
$^{81}Kr^{m}$	- Lung ventilation imaging
	- Lung perfusion imaging
▪ ^{111}In, $^{113}In^{m}$ (Non-absorbable)	
	- Gastric emptying
▪ ^{75}Se	- Adrenal imaging

Accidents

- **Definition:** Any unintended event, including operating errors, equipment failures and other mishaps, whose consequences or potential consequences cannot be ignored from the radiation and safety point of view and which can lead to ***potential exposure*** and subsequently to abnormal exposure conditions **(BSS 115).**

Accidents…

- **Potential exposure –** Exposure that may or may not be delivered and to which a probability of occurrence can be assigned
- **Safety Culture –** The assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the highest attention warranted by their significance.

Accidents – Example 1

- An 87 year old patient was administered a therapy dose of I-131 (7.4 GBq) in the hope of relieving oesophageal compression caused by metastatic thyroid carcinoma. About 34 hrs after receiving the dose, the patient had cardiopulmonary arrest and expired. Attempts at resuscitation were made in the patients room by 16 staff members. The efforts included insertion of a pace maker. Contaminated blood and urine were spilled and no surveys of the clothing of those present were done. The highest personnel monitoring reading was 0.3mGy for one of the nurses. Subsequent thyroid uptake measurements showed uptake by involved staff

Accidents..

- **Initiating event:** Heart failure of patient shortly after iodine therapy
- **Contributing factor**: Contingency procedures for emergency situations involving radionuclides were not available. Monitoring instruments and decontamination equipment were not available

Accidents – Example 2

- The wrong patient was administered
- Initiating event: A patient responded to another patient's name being called.
- **Contributing factor**: Hospital protocol for identification of patients was not followed

How to avoid accidents

- Safety culture
- Safety assessment to define critical procedures and emergency situations
- Reporting system (when? Where? Why?)
- Education and training – initial, continuing

Causes of misadministration of radiation sources

- Communication problems
- Busy environment, distraction
- Unknown/absence of local rules
- No training in ER situations
- No clearly defined responsibilities
- No efficient quality assurance

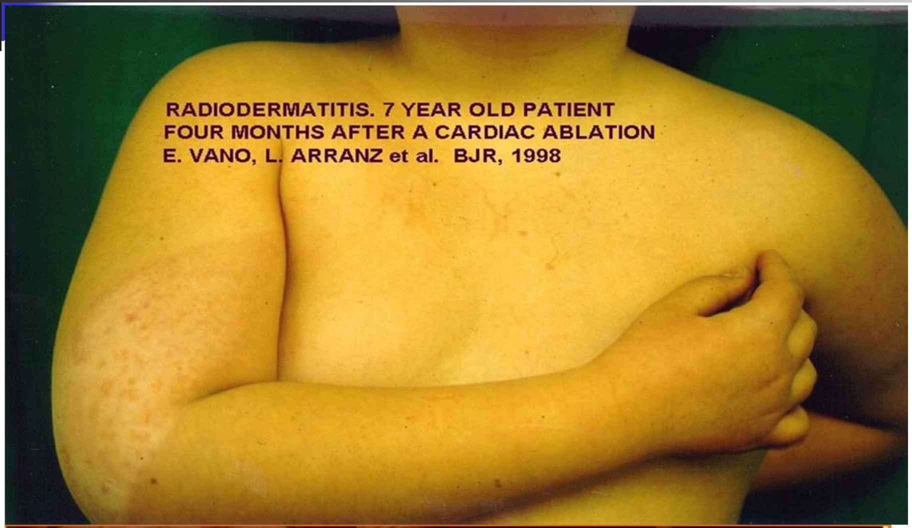
Consequences of misadministration

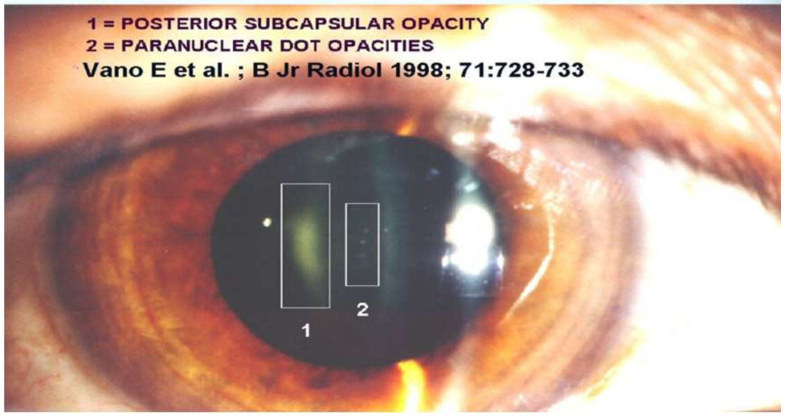
- Non justified exposure
- Increased radiation risks
- Delayed diagnosis
- Increased costs
- Increased workload
- Reduced confidence (person/institution)

Death of a therapy patient

- Occasionally the condition of a patient treated with radionuclides may lead to death while the body still contains substantial residual activity
- (**Radiopharmaceutical or brachytherapy needles**)

Radiation Injuries





Links

- https://hps.org/hpspublications/articles/dosesfrommedicalradiation.html
- http://www.radiologyinfo.org/en/info.cfm?pg=safety-xray

QUESTIONS?

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