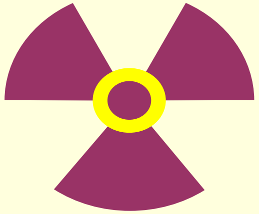
Dosimetry

of

ionizing radiation



Ionizing radiation

Classification according to the primary effect

↙ ↘

Direct ionization	*Indirect ionization*
Incoming particles already held charges. E.g. α- and β-particles.	Primary electrons ejected by the photons and secondary electrons present charges. e.g. γ-radiation, X.ray.

Ionizing radiation

Discovery
(X-ray, radioactivity etc.)

☺

Application
(enjoy benefits)

☹

Dosimetry
(optimization of benefits, estimation of risk and hazard)

Task for dosimetry

Estimation of health risk for prevention.

Estimation of biological damages.

Design of therapeutic procedures.

Definition of quantities

↓

Design of measuring techniques

↓

Estimation of consequences

1. Dose values sholud be

- proportional to the damagas and expected risk !
- additiv
- independent of other factors!?

Dose concepts

Physical dose concepts:
Absorbed dose,
Exposure

→

Biological dose concepts:
Equivalent dose,
Effective dose

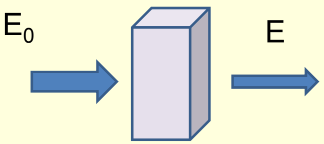
→

Derived dose concepts:
Collective dose,
Dose rate

1. Absorbed dose

measures the absorbed energy in a unit mass

$\Delta E = E_0 - E$



$$D = \frac{\Delta E}{\Delta m} [J/kg]$$

Validity: for any kind of material and any type of radiation without restriction

Louis Harold Gray
(1905-1965).

Unit: $[J/kg] \equiv Gy$

How to be measured ????

^{131}I of 0.2 GBq activity is accumulated in 80 g thyroid glands. The effective half-life is 7.5 days . Average β-particle energy is 0.18 MeV. Assume that the particles are fully absorbed in the thyroid glands . What is the absorbed dose in the given tisssue?

$$\Lambda = \frac{\ln 2}{T} N \qquad N = \frac{0{,}2 * 10^9 [Bq] * 6{,}48 * 10^5 [s]}{0{,}693} = 1{,}87 * 10^{14}$$

$$E_{sum} = N * E \qquad E = 0{,}18 * 10^6 [eV] = 2{,}88 * 10^{-14} [J]$$

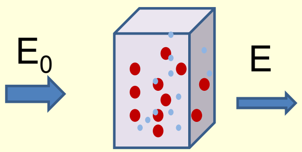
$$E_{össz} = 1{,}87 * 10^{14} * 2{,}88 * 10^{-14} = 5{,}38 [J]$$

$$D = \frac{E_{sum}}{m}$$

$$D = \frac{5{,}38}{0{,}08} = 67{,}28 \left[\frac{J}{kg}\right]$$

2. Exposure

measures the amount of positive or negative charges generated by the radiation in a unit mass.



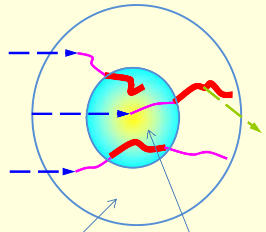
$$X = \frac{\Delta Q}{\Delta m}[C/kg]$$

Validity: in the air, only γ and X –rays, measured in electron equilibrium*

$$X = \frac{\Delta Q}{\Delta m}[C/kg]$$

ΔQ – secondary electrons!!

Electron-equilibrium : net number of the secondary electrons living and entering volume of the cavity are equal.



To be considered:

- composition of surrounding material (chamber wall) –
  air-equivalent wall!
- thickness of the wall
- Photon energy: E< 0.6 MeV

Calculation of the absorbed dose from the exposure

$$X = \frac{\Delta Q}{\Delta m}[C/kg] \qquad D_{air} = f_0 X \qquad D = \frac{\Delta E}{\Delta m}[J/kg]$$

~ 34 J/C

Average ionization energy in air

~ 34 eV.

Absorbed dose in tissue

$$\frac{\Delta E}{\Delta m} \approx \mu_m \cdot J$$

$$D_{air} = \frac{\Delta E}{\Delta m}[J/kg]$$

$$\frac{D_{air}}{D_{tissue}} = \frac{\mu_{m.air}}{\mu_{m,tissue}}$$

Photon energy (MeV)	$\mu_{m,air}/\mu_{m,tissue}$ (soft tissues)	$\mu_{m,air}/\mu_{m,tissue}$ (bones)
0,1	1,07	3,54
0,2	1,08	2,04
0,4	1,10	1,24

Biological dose concepts

Equivalent dose

Effective dose

The absorbed energy (absorbed dose) is not sufficient to measure the possible biological consequences.

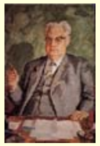
The biological consequences are influenced by :

the type of radiation. → radiation weighting factor

the sensitivity and biological function of target → tissue weighting factor

Equivalent dose (H)

Rolf Sievert
1896-1966



„Efficiency" of various forms of radiation is not uniform.

$$H_T = w_R D_T$$

Radiation weighting factor – estimation of the relative risk of the given radiation

Absorbed dose in tissue

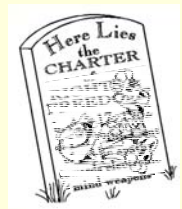
Unit of ***H*** : ***Sievert (Sv)***

radiation	W_R
photon	1
electron	1
neutron	5-20
proton	5
α-particle	20

Why are the fates of the rabbits different?

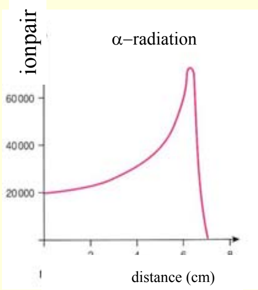
2 Gy absorbed dose – ***X-ray***

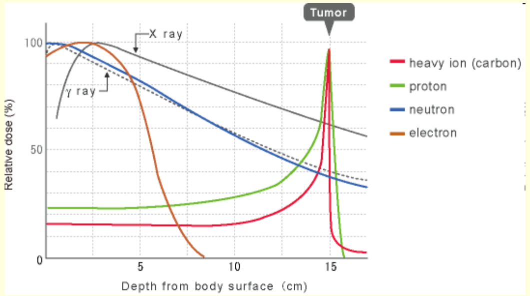
2 Gy absorbed dose – ***α-particles***



Equivalent dose (H)

„Efficiency" of various forms of radiation is not uniform.

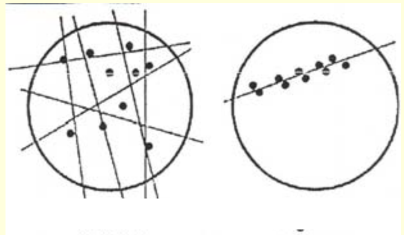




LET (Linear Energy Transfer : the energy transferred to the material surrounding the particle track, by means of secondary electrons. *(nE*$_{ionpair}$*/l)*

Equivalent dose (H)

„Efficiency" of various forms of radiation is not uniform.



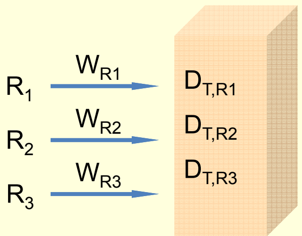
Small LET
e.g. γ, -ray

High LET
e.g.. α, proton

$$H_T = w_R D_T$$

radiatiom	W_R
photon	1
electron	1
neutron	5-20
proton	5
α-particle	20

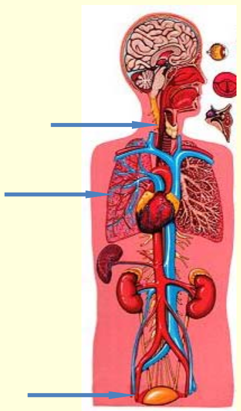
If someone is exposed to more than one type of radiation:



$$H_T = \sum_R w_R D_{T,R}$$

Effective dose (E)

Various sensitivity of tissues has to be considered



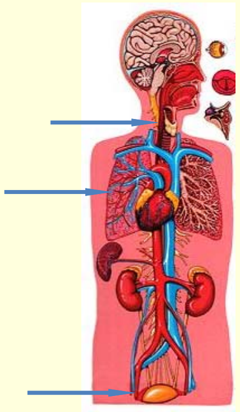
$$E = \sum_T w_T H_T$$

Tissue weighting factor – estimation of the relative sensitivity of tissue

Equivalent dose in the given tissue

Unit of ***E*** : ***Sievert (Sv)***

$$E = \sum_T w_T H_T$$



tissue	W_T	tissue	W_T
gonads	0,2	breast	0,05
bone marrow	0,12	liver	0,05
colon	0,12	oesophagus	0,05
lung	0,12	thyroid gland	0,05
stomach	0,12	skin	0,01
bladder	0,05	bone surface	0,01

$$\sum_T w_T = 1$$

Dose rate

Received dose over time.

Unit: varies with the type of radiation and the time period (pl. Gy/month, mSv/year etc.)

Collective dose

Sum of the doses received by a given number of people (N_i) in the course of a given time interval.

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Sum of the doses received by a given number of people (N_i) in the course of a given time interval.

$$S = \sum_i N_i E_i$$

E_i effective dose in each person

Damjanovich, Fidy, Szöllősi: Medical Biophysics

II. 4.
- 4.1
- 4.2
- 4.3
- 4.4
- 4.5

In the frame: 184. 186.

Manual :Dosimetry