Complement:
Natural sources of radiations

Notions of dose

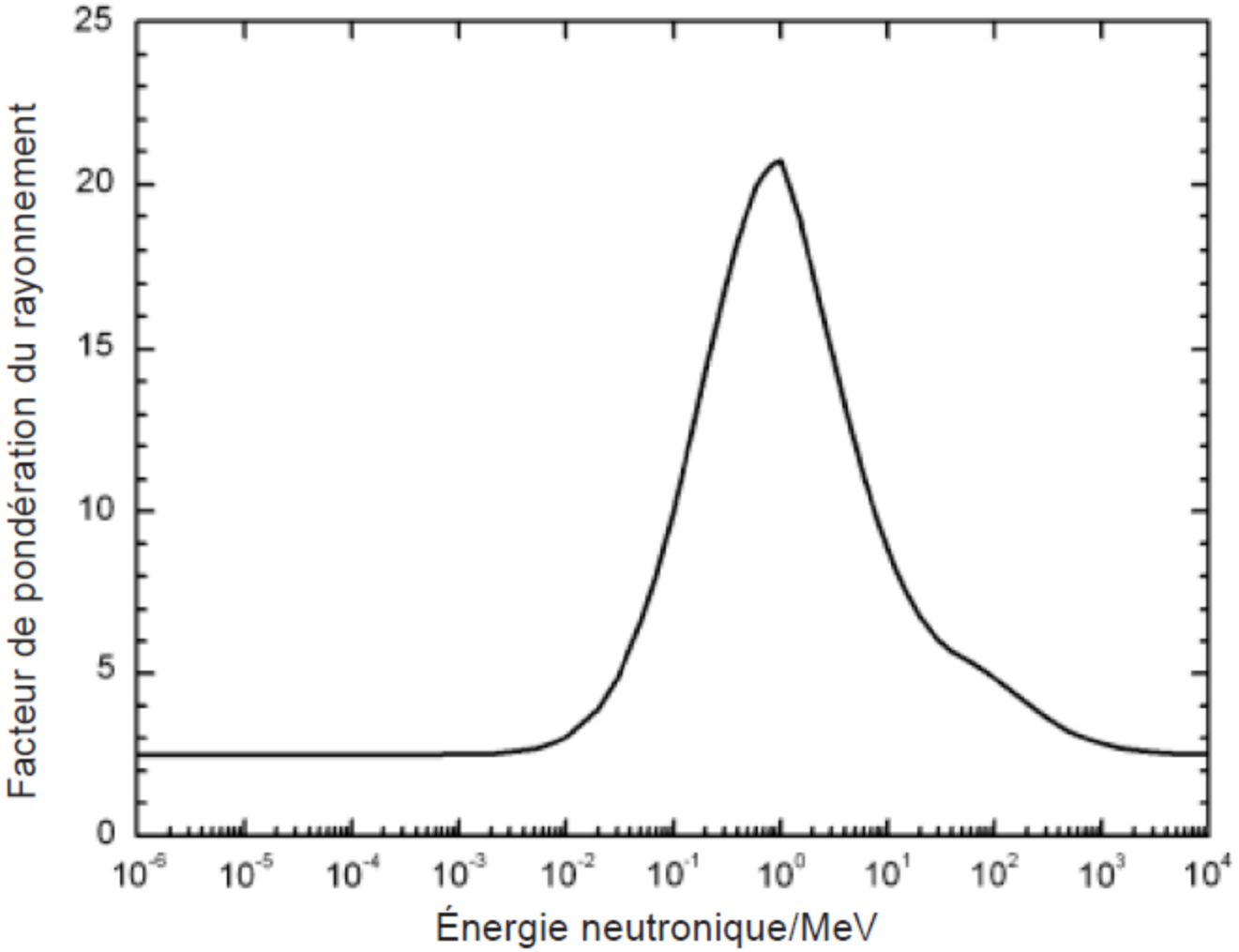
- Absorbed dose at 1 point (D): Mean value of the energy deposited by ionizing radiation to matter per mass unit (unit: J/kg = gray (Gy))
- Equivalent dose in an organ or a tissue (H): Dose taking into account the risks for an human due to various types and energies of ionizing radiations → the equivalent dose is calculated by multiplying the absorbed dose by a radiation weighting factor, w_R, appropriate to the type and energy of radiation (unit: J/kg = sievert (Sv))

$$H = w_R D_R$$

Ponderation factors for radiations (ICRP 103)

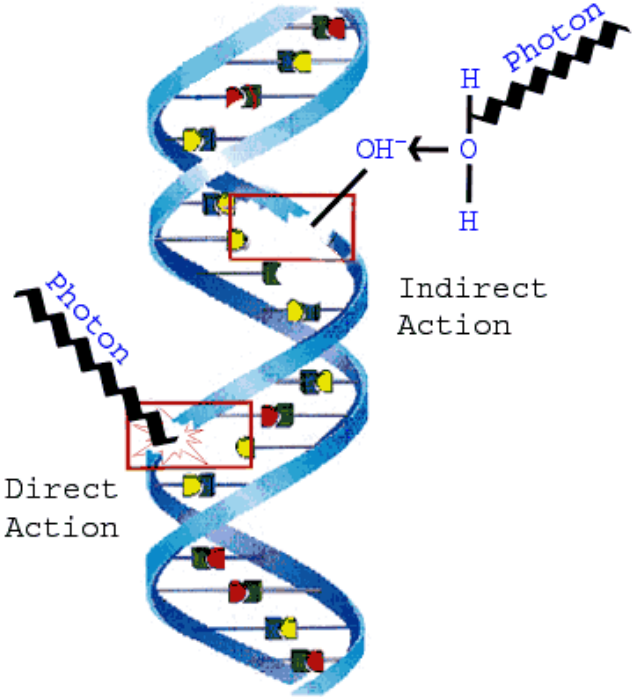
Type de rayonnement	Facteur de pondération pour les rayonnements, w_R
Photons	1
Électrons[a] et muons	1
Protons et pions chargés	2
Particules alpha, fragments de fission, ions lourds	20
Neutrons	Une fonction continue de l'énergie des neutrons

Ponderation factors for neutrons (ICRP 103)



Considered energy

- Typical energy considered in radiation dosimetry is weak (example: semi-lethal dose for uniform exposure to X-ray field: 4 Gy → for human of 70 kg → 280 J) → effects of ionizing radiations can be explained because the energy is delivered locally at molecular scale



Legal limitations of dose

- For public → Maximal dose/year = 1 mSv (with the exception of dose due to medical examinations)
- Pour workers professionally exposed → Limitation up to 20 mSv/year
- For pregnant women → 1 mSv during pregnancy
- These values do not take into account natural irradiation
- Thresholds exist for particular parts of the body (crystalline, extremities,…)

Natural and non-natural sources of radiations

- Natural background radiations come from three sources:

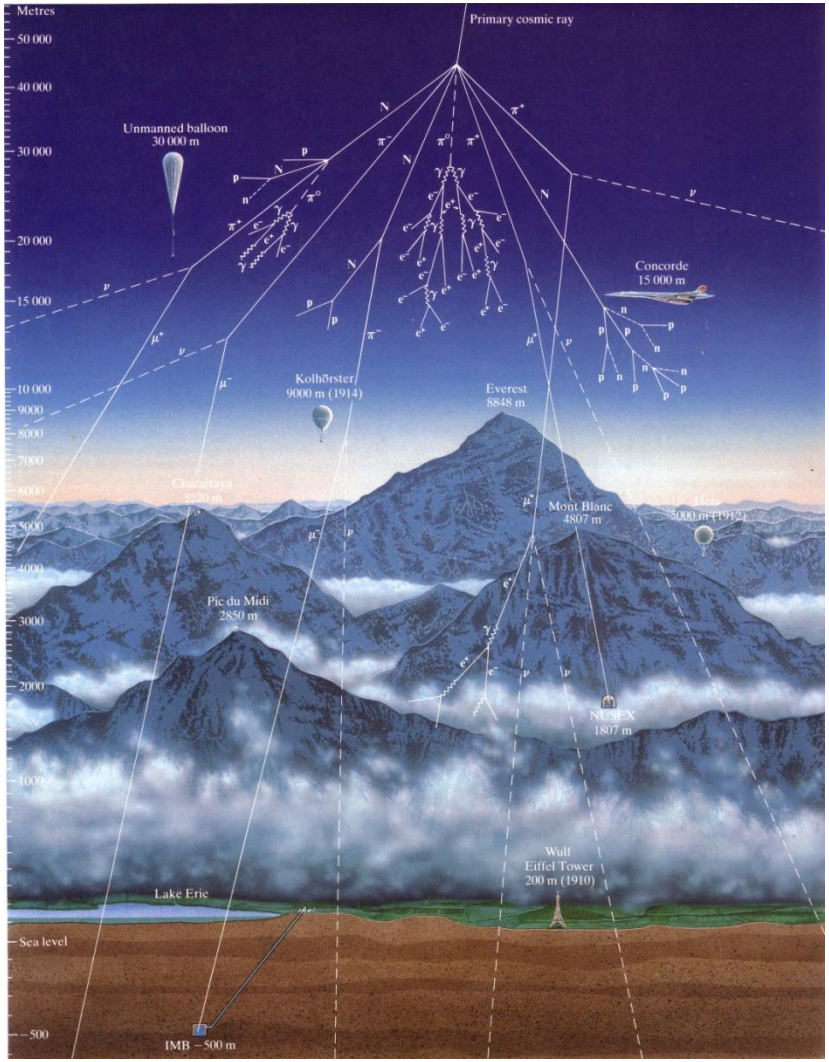
1. Cosmic radiations
2. Terrestrial radiations
3. Internal radiations

- The most important « non-natural » source results from medical examinations

Cosmic radiations

- The Earth is constantly bombarded by cosmic rays
- These radiations can have small energy → come from the Sun or large energy (can reach 10^{15} - 10^{20} eV) → come from outside the solar system (supernova or pulsars)
- Cosmic radiation is protons at 90%
- Charged particles interact with the nuclei of Earth atmosphere → production of a shower of radiation → some of them reach the ground → source of radiations → typically muons and γ radiations

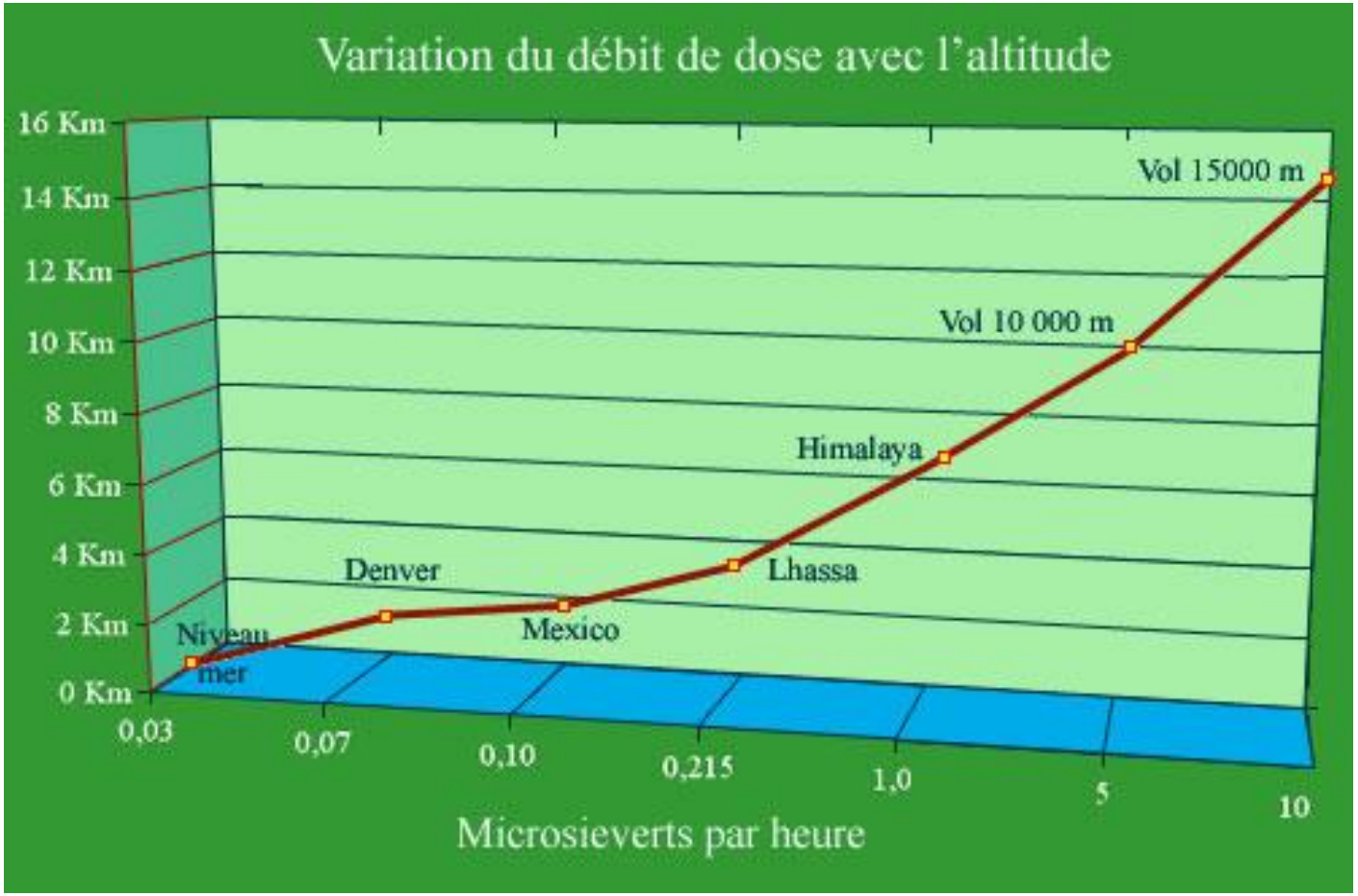
Cosmic shower



Dose due to cosmic rays

- The dose from cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the Earth magnetic field
- Mean exposure in Belgium is about 0.25 mSv/year
- For a typical cross-country flight in a commercial airplane (altitude of ≈ 8000 m), the dose is ≈ 100 $\times$ larger than at the see level → the passenger of a flight London-New York receives a dose of about 0.03 mSv → remark: the flight staff is not controlled
- During space flights → astronauts receive a dose of about 1 mSv/day

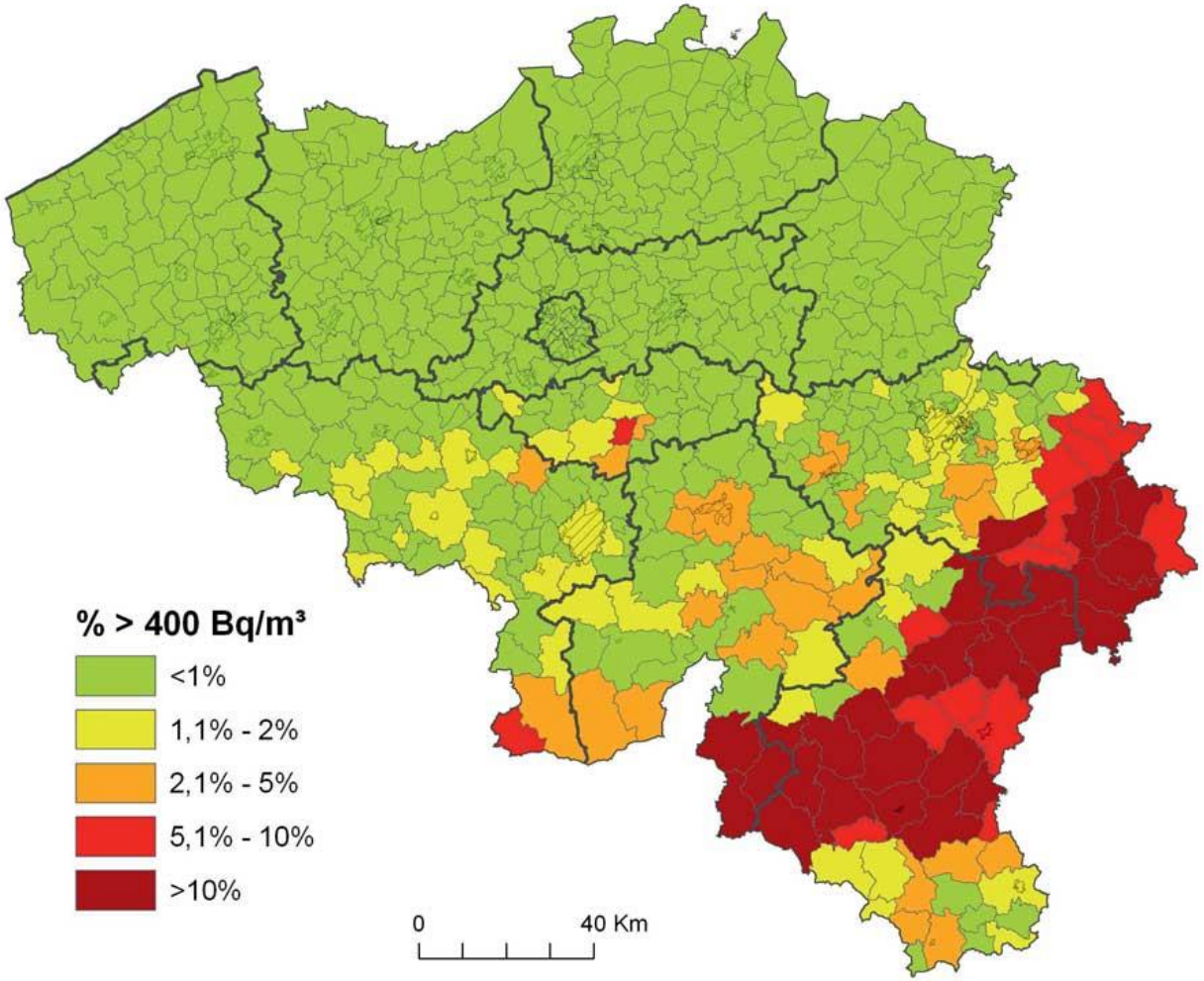
Elevation effect



Terrestrial radiations

- The earth's crust contains des very long live (a few billions oy years) → source of natural radioactivity: ^{232}Th, ^{235}U, ^{238}U
- With filiation products → responsible for terrestrial radiations
- Some of these isotopes could be ingested and some other inhaled (220 and 222 radon)
- The dose from terrestrial sources also varies in different parts of the world → locations with higher concentrations of uranium and thorium in their soil have higher dose levels (as in the Ardennes)

Terrestrial radiation in Belgium



In Belgium → the radon dose is estimated to ≈ 1 mSv/year (large variations)

Guarapari - Brésil

- On the Guarapari beach → sand rich in monazite: mineral containing ≈ 10% of thorium → dose rate in some places: 20 μSv/h → 175 mSv/year
- « Radioactivity baths » → publicity for healing properties

Ramsar - Iran

- Ramsar region in Iran is a touristic place: spa towns → hot radioactive sources → 260 mSv/year
- For local populations → 130 mSv/year

Kerala -Inde

Table des malformations

Dose (mGy/an)	Nbre total de nouveau-nés	Nbre avec malformations	
< 1,5	10 654	147	1,38%
1,5 à 3	22 599	337	1,49%
3 à 6	2 195	30	1,37%
6 à 18	975	18	1,85%
> 18	382	6	1,57%

Exposition au rayonnement naturel très élevé de 1 à plus de 35 mSv par an.

« The rate of malformations is not connected to the level of rock radiations »

Internal radiations

- We ingest and inhale continuously radioactive elements → we are irradiated from inside our body
- More of the half of internal radiation comes from potassium (^{40}K)
- The level of ^{14}C is important also
- Emission of β → internal exposure and of γ → external exposure
- The average annual dose to a person from internal radioactive material is about 0.25 mSv
- The variation in dose from one person to another is not as great as the variation in dose from cosmic and terrestrial sources

^{40}K activity

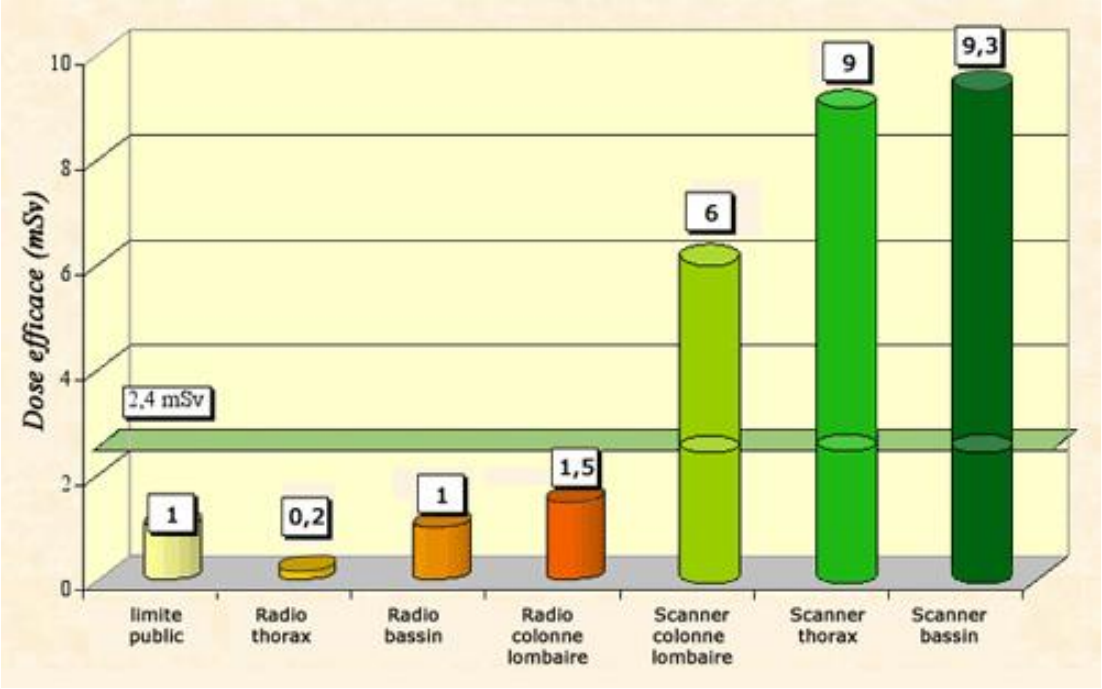
Activité du potassium-40 dans divers aliments

Produit	Activité en Bq/kg
Lait entier	44
Lait en poudre	300
Fromage	59
Boeuf, mouton, volaille	100
Saucisse	130
Oeufs	44
Poisson	90
Pommes de terre	170
Fruits rouges	110
Legumes verts	150
Pain blanc	56
Avoine	130
Soja	440
Thé	770

UIR
EULEP
EURADOS

Dose from medical examinations

- Variable → good health: 0 mSv/year and for other ones: a few tens of mSv/year



- Mean value in Belgium: 1.5 mSv/an

Ionizing radiation exposure to the public