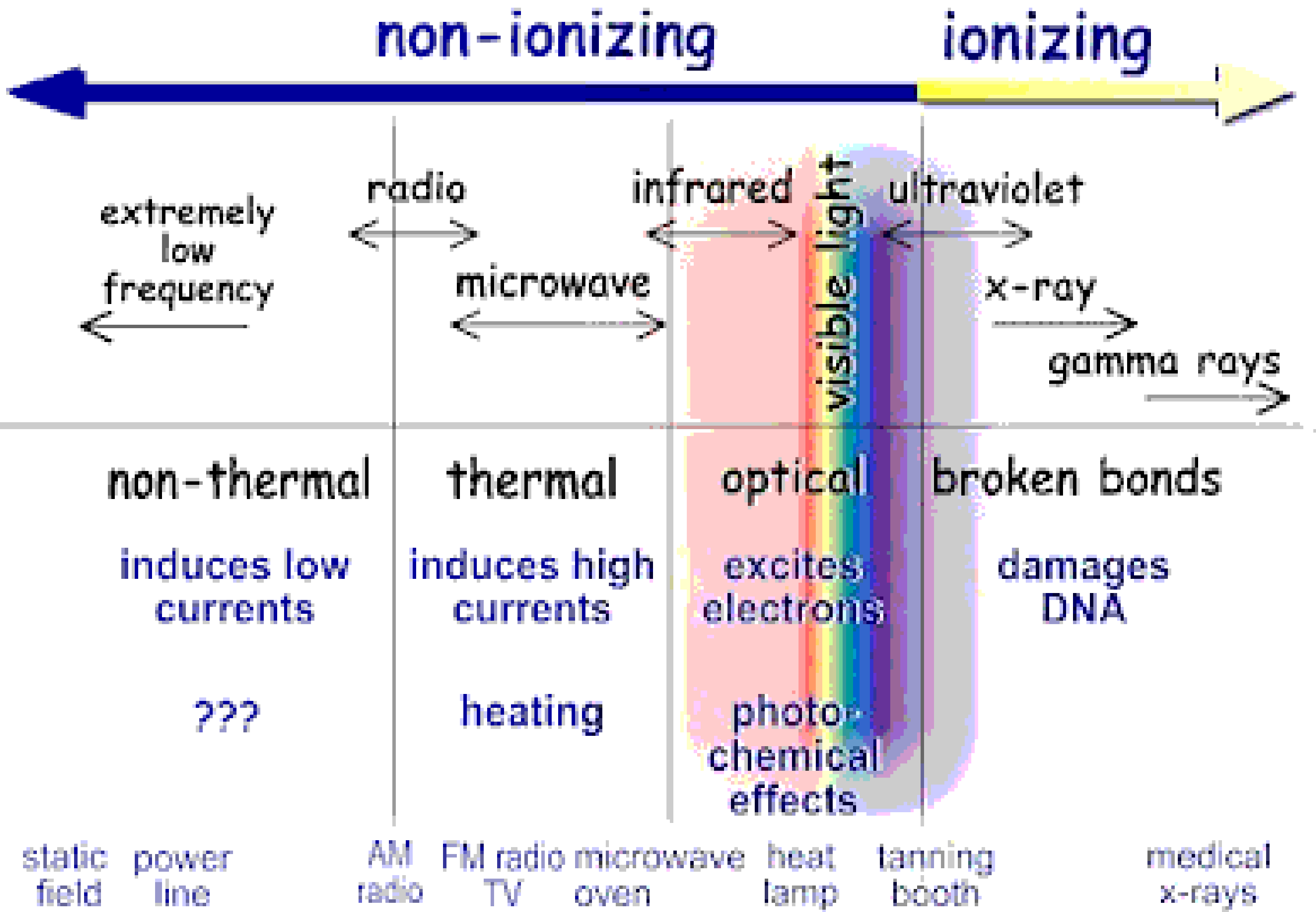

non-ionizing
ionizing
extremely low frequency
radio
microwave
infrared
visible light
ultraviolet
x-ray
gamma rays
non-thermal
thermal
optical
broken bonds
induces low currents
induces high currents
excites electrons
damages DNA
???
heating
photo-chemical effects
static field
power line
AM radio
FM radio TV
microwave oven
heat lamp
tanning booth
medical x-rays

Resumen de unidades

- **Activity** is the transformation (disintegration) rate of a radioactive substance
  - Curie (Ci)
  - Becquerel (Bq) - S.I. Unit

1 Bq = 1 disintegration per second (dps) 1 Ci = 3.7×10^{10} dps = 3.7×10^{10} Bq

- **Absorbed dose** is a physical quantity which represents the energy imparted by radiation onto an absorbing material.
  - Rad = 100 ergios / 1g
  - Gray (Gy) - SI Unit 1 Gy = 1 joule per kilogram 1 Gy = 100 rads

- **Dose Equivalent (DE)** may be regarded as an expression of dose in terms of its biological effect. DE takes account of the fact that, for a given absorbed dose, such as 1 Gray, a radiation of one type and/or energy may give rise to a greater biological effect than a radiation of another type and/or energy.

  DE = Absorbed Dose x Quality Factor (Q) , Q depends on the type of radiation.
  - Q = 1 for gamma, x-ray and beta
  - Q = 10 for alpha

    Q is used to compare the biological damage producing potential of various types of radiation, given equal absorbed doses. The effectiveness of radiation in producing damage is related to the energy loss of the radiation per unit path length. The term used to express this is Linear Energy transfer (LET). Generally, the greater the LET in tissue, the more effective the radiation is in producing damage.
  - rem (Roentgen Equivalent Man)
  - SIEVERT (Sv) - S.I. Unit 1 Sv = 100 rems

- **Exposure** is a quantity that expresses the ability of radiation to ionize air and thereby create electric charges which can be collected and measured
  - Roentgen (R) 1 R = 2.58×10^{-4} C/kg of air
  - 1 R = 0.01 Sv

Dose equivalent

The equivalent dose to a tissue is found by multiplying the absorbed dose, in gray, by a weighting factor (W_R). The relation between absorbed dose D and equivalent dose H is thus:

$$H = W_R \cdot D.$$

The weighting factor (sometimes referred to as a quality factor) is determined by the radiation type and energy range.[1]

$$H_T = \sum_R W_R \cdot D_{T,R} \ ,$$

where

H_T is the equivalent dose absorbed by tissue T
$D_{T,R}$ is the absorbed dose in tissue T by radiation type R
W_R is the weighting factor defined by the following table

Radiation type and energy		W_R
electrons, muons, photons (all energies)		1
protons and charged pions		2
alpha particles, fission fragments, heavy ions		20
neutrons (function of linear energy transfer L in keV/μm)	$L < 10$	1
	$10 \leq L \leq 100$	$0.32 \cdot L - 2.2$
	$L > 100$	$300 / \mathrm{sqrt}(L)$

Thus for example, an absorbed dose of 1 Gy by alpha particles will lead to an equivalent dose of 20 Sv. The maximum weight of 30 is obtained for neutrons with $L = 100$ keV/μm.

The *effective dose* of radiation (E), absorbed by a person is obtained by averaging over all irradiated tissues with weighting factors adding up to 1

$$E = \sum_T W_T \cdot H_T = \sum_T W_T \sum_R W_R \cdot D_{T,R}.$$

Tissue type	***W*T (each)**	***W*T (group)**
Bone marrow, colon, lung, stomach, breast, remaining tissues	0.12	0.72
Gonads	0.08	0.08
Bladder, oesophagus, liver, thyroid	0.04	0.16
Bone surface, brain, salivary glands, skin	0.01	0.04
total		**1.00**

For other organisms, weighting factors have been defined, relative to the effect on humans:[2]

Organism	**relative weight**
Viruses, bacteria, protozoans	0.03 – 0.0003
Insects	0.1 – 0.002
Molluscs	0.06 – 0.006
Plants	2 – 0.02
Fish	0.75 – 0.03
Amphibians	0.4 – 0.14
Reptiles	1 – 0.075
Birds	0.6 – 0.15

Symptoms frameworks

- **Symptoms of acute radiation** (dose received within one day):
  - 0 – 0.25 Sv (0 – 250 mSv): None
  - 0.25 – 1 Sv (250 – 1000 mSv): Some people feel nausea and loss of appetite; bone marrow, lymph nodes, spleen damaged.
  - 1 – 3 Sv (1000 – 3000 mSv): Mild to severe nausea, loss of appetite, infection; more severe bone marrow, lymph node, spleen damage; recovery probable, not assured.
  - 3 – 6 Sv (3000 – 6000 mSv): Severe nausea, loss of appetite; hemorrhaging, infection, diarrhea, peeling of skin, sterility; death if untreated.
  - 6 – 10 Sv (6000 – 10000 mSv): Above symptoms plus central nervous system impairment; death expected.
  - Above 10 Sv (10000 mSv): Incapacitation and death.
- **Dose examples**
  - Dental radiography: 0.005 mSv
  - Mammogram — Single Exposure, Equipment Mean: 2 mSv
  - Mammogram — Procedural Mean, Equipment Variation: 4 mSv - 5 mSv
  - Brain CT scan: 0.8–5 mSv
  - Chest CT scan: 6–18 mSv
  - Gastrointestinal series X-ray investigation: 14 mSv
  - International Commission on Radiological Protection recommended limit for volunteers averting major nuclear escalation: 500 mSv
  - International Commission on Radiological Protection recommended limit for volunteers rescuing lives or preventing serious injuries: 1000 mSv[10]
- **Hourly dose examples**
  - Average individual background radiation dose: 0.23μSv/h (0.00023mSv/h); 0.17μSv/h for Australians, 0.34μSv/h for Americans
  - Highest reported level during Fukushima accident: 1000 mSv/h reported as the level at a pool of water in the turbine room of reactor two.

- **Yearly dose examples**
  - Maximum acceptable dose for the public from any man made facility: 1 mSv/year
  - Dose from living near a nuclear power station: 0.0001–0.01 mSv/year
  - Dose from living near a coal-fired power station: 0.0003 mSv/year
  - Dose from sleeping next to a human for 8 hours every night: 0.02 mSv/yr
  - Dose from cosmic radiation (from sky) at sea level: 0.24 mSv/year
  - Dose from terrestrial radiation (from ground): 0.28 mSv/year
  - Dose from natural radiation in the human body: 0.40 mSv/year
  - Dose from standing in front of the granite of the United States Capitol building: 0.85 mSv/year
  - Average individual background radiation dose: 2 mSv/year; 1.5 mSv/year for Australians, 3.0 mSv/year for Americans
  - Dose from atmospheric sources (mostly radon): 2 mSv/year
  - Total average radiation dose for Americans: 6.2 mSv/year
  - New York-Tokyo flights for airline crew: 9 mSv/year
  - Dose from smoking 30 cigarettes a day: 13-60 mSv/year
  - Current average dose limit for nuclear workers: 20 mSv/year
  - Dose from background radiation in parts of Iran, India and Europe: 50 mSv/year
  - Dose limit applied to workers during Fukushima emergency: 250 mSv/year

- **Dose limit examples**
  - Criterion for relocation after Chernobyl disaster: 350 mSv/lifetime
  - In most countries the current maximum permissible dose to radiation workers is 20 mSv per year averaged over five years, with a maximum of 50 mSv in any one year.
  - This is over and above background exposure, and excludes medical exposure. The value originates from the International Commission on Radiological Protection (ICRP), and is coupled with the requirement to keep exposure as low as reasonably achievable (ALARA) – taking into account social and economic factors.
  - Public dose limits for exposure from uranium mining or nuclear plants are usually set at 1 mSv/yr above background.

History

Historically, the weighting factors for radiation type and tissue type were separated out as Q and N respectively. In 2002, the CIPM decided that the distinction between Q and N caused too much confusion and therefore deleted the factor N from the definition of absorbed dose in the SI brochure.[22]

The older version of the definitions contained Q and N factors, corresponding to the current W_R and W_T, with values:

Radiation type and energy	Q
electrons, positrons, muons, or photons (gamma, X-ray)	1
neutrons <10 keV	5
neutrons 10–100 keV	10
neutrons 100 keV – 2 MeV	20
neutrons 2 MeV – 20 MeV	10
neutrons >20 MeV	5
protons other than recoil protons and energy >2 MeV	2
alpha particles, fission fragments, nonrelativistic heavy nuclei	20

Tissue type	N (each)	N (group)
bone surface, skin	0.01	0.02
bladder, breast, liver, esophagus, thyroid, other	0.05	0.30
bone marrow, colon, lung, stomach	0.12	0.48

RADIACTIVIDAD NATURAL

Radiactividad Natural en la Comida

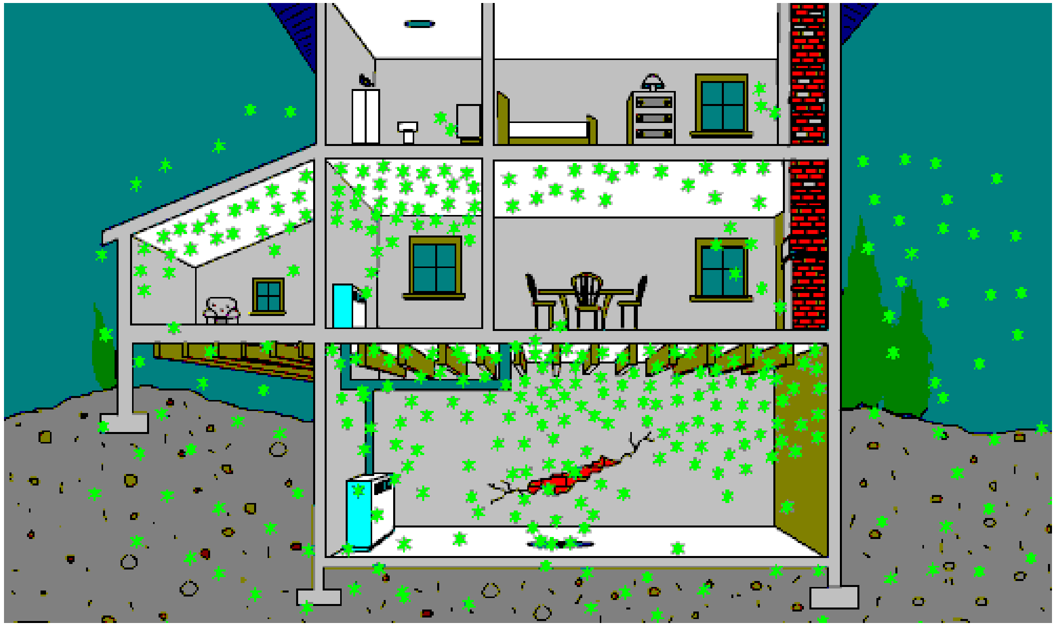
La radiación interna proviene de las sustancias radiactivas presentes en los alimentos, en el agua y en el aire, las cuales, al ser ingeridas o inhaladas, se absorben en los tejidos vivos. Los principales isótopos radiactivos que contiene el cuerpo humano son el potasio-40, el carbono-14 y el tritio

Comida	^{40}K pCi/kg	^{226}Ra pCi/kg
Plátano	3,520	1
Nueces	5,600	1,000-7,000
Zanahorias	3,400	0.6-2
Patatas	3,400	1-2.5
Cerveza	390	---
Carne Roja	3,000	0.5
Limón	4,640	2-5
Agua del Grifo	---	0-0.17

NOTA: 1Ci = 1 Curio = $3.7x10^{10}$ Bq
1 Bq = 1 Becquerel = 1 desintegración / s

RADIACTIVIDAD NATURAL

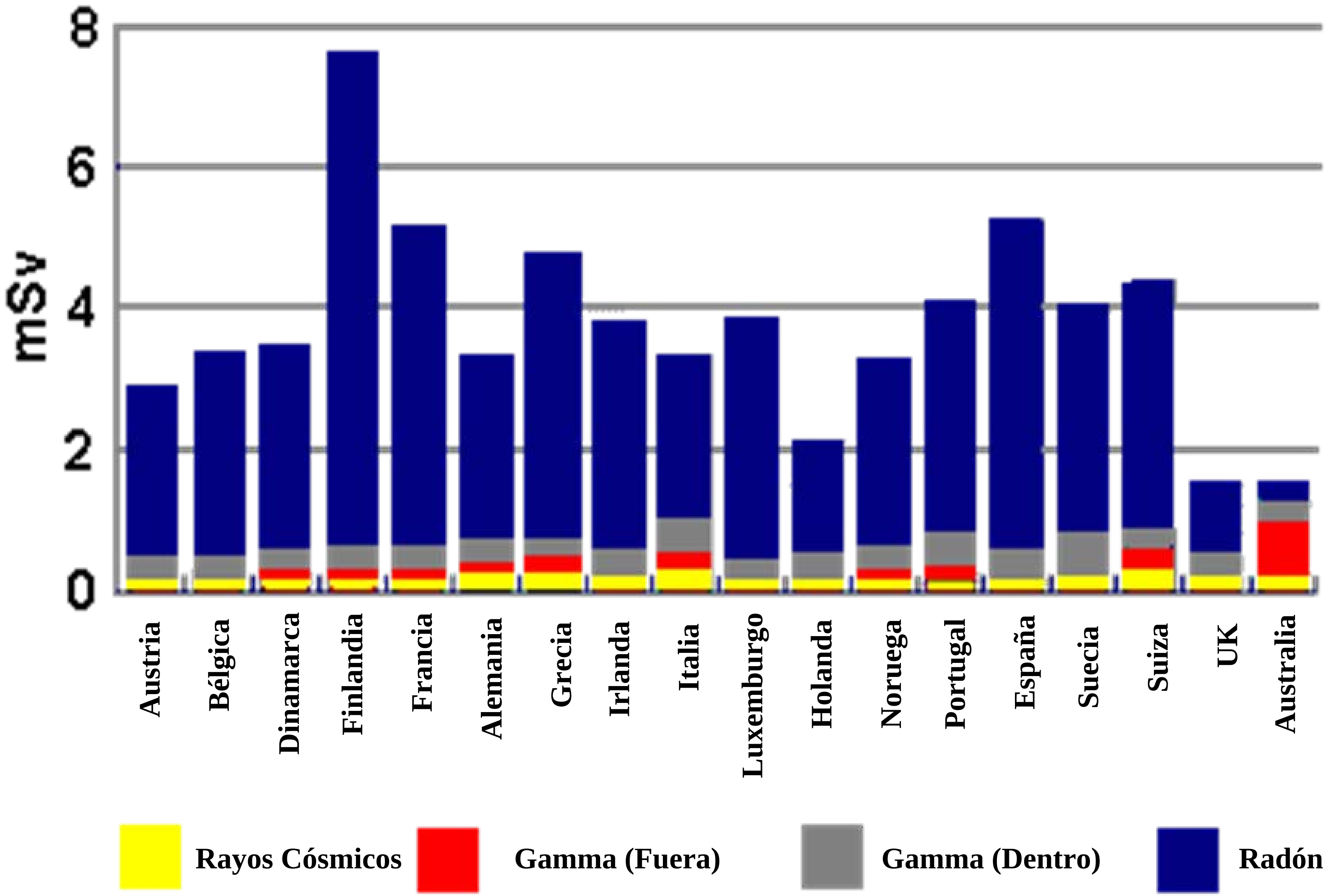
El Radón en Nuestras Vidas



El Radón es una de las principales sustancias que contribuye a la dosis que recibimos de manera natural.
El Radón es un gas noble que se filtra hasta el interior de nuestras casas desde el subsuelo.

Es curioso observar cómo ésta dosis es mayor en países fríos, donde ventilar la casa puede costar algún catarro

DOSIS MEDIA ANUAL PROVENIENTE DE RADIACIÓN NATURAL



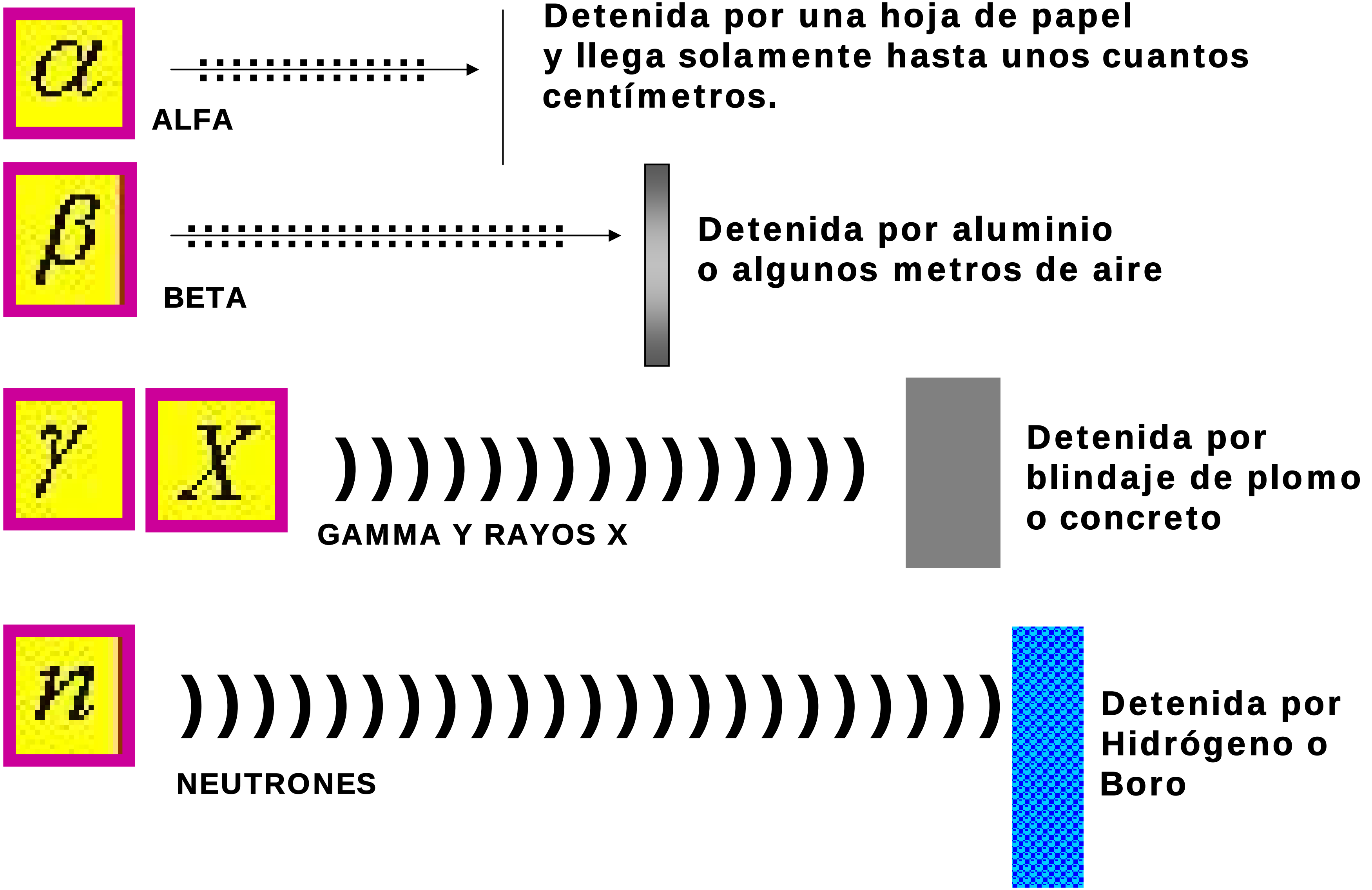
EJEMPLO 1:

Un trabajador que haya recibido el vigente limite anual de dosis para trabajadores expuestos (50 mSv) cada año de su vida laboral (47 años), habrá acumulado una dosis de 47 x 50 = 2350 mSv = 2.35 Sv. Multiplicando este valor por el detrimento de desarrollar un cáncer mortal para trabajadores ($4x10^{-2}$=0.04 Sv^{-1}) resulta un riesgo o probabilidad de que la causa de la muerte de la persona sea un cáncer mortal debido a su exposición a las radiaciones ionizantes de 0.094=9.4%. La probabilidad de aparición del mismo cáncer por otras causas es de un 35% debido a la alimentación, un 30% debido al tabaco, un 7% debido a prácticas sexuales, un 3% debido al alcohol, etc (Doll y Peto, 1981). Es decir, si la persona fallece de cáncer, la probabilidad de que la causa del mismo sea a la exposición profesional a las radiaciones ionizantes es inferior o del mismo orden que las debidas a otros agentes relacionados con aspectos cotidianos de la vida.

EJEMPLO 2:

Una persona que haya recibido el vigente límite de dosis anual para el público (1 mSv) cada año de su vida (90 años) por el impacto de una instalación radiactiva o nuclear, habrá acumulado una dosis de 90 x 1 = 90 mSv = 0.09 Sv. Multiplicando este valor por el detrimento total para la población en general ($7.3x10^{-2}$=0.073 Sv^{-1}) resulta un riesgo de 0.00657=0.66%. Esta es la probabilidad de que la muerte de la persona se deba a su exposición a las radiaciones ionizantes. En otras palabras, existe una probabilidad mayor del 99% de que la causa del deceso sea debida a otras causas.

TIPOS DE RADIACIONES IONIZANTES



Ejemplos de efectos radiación

- Estocasticos
  - **Cáncer**
  - **Malformaciones y enfermedades hereditarias**
  - **Tumores malignos**
  - **Leucemias**

- Deterministas
  - **Cataratas oculares**
  - **Eritema**
  - **Cáncer cutáneo**
  - **Alteraciones hematológicas**
  - **Aplasia medular**
  - **Anemias**
  - **Caída del cabello**
  - **Inflamación bronquial**
  - **Fibrosis pulmonar**
  - **Neumonitis**
  - **Esterilidad**

CUADRO HIPER-AGUDO (EFECTOS INMEDIATOS en minutos)

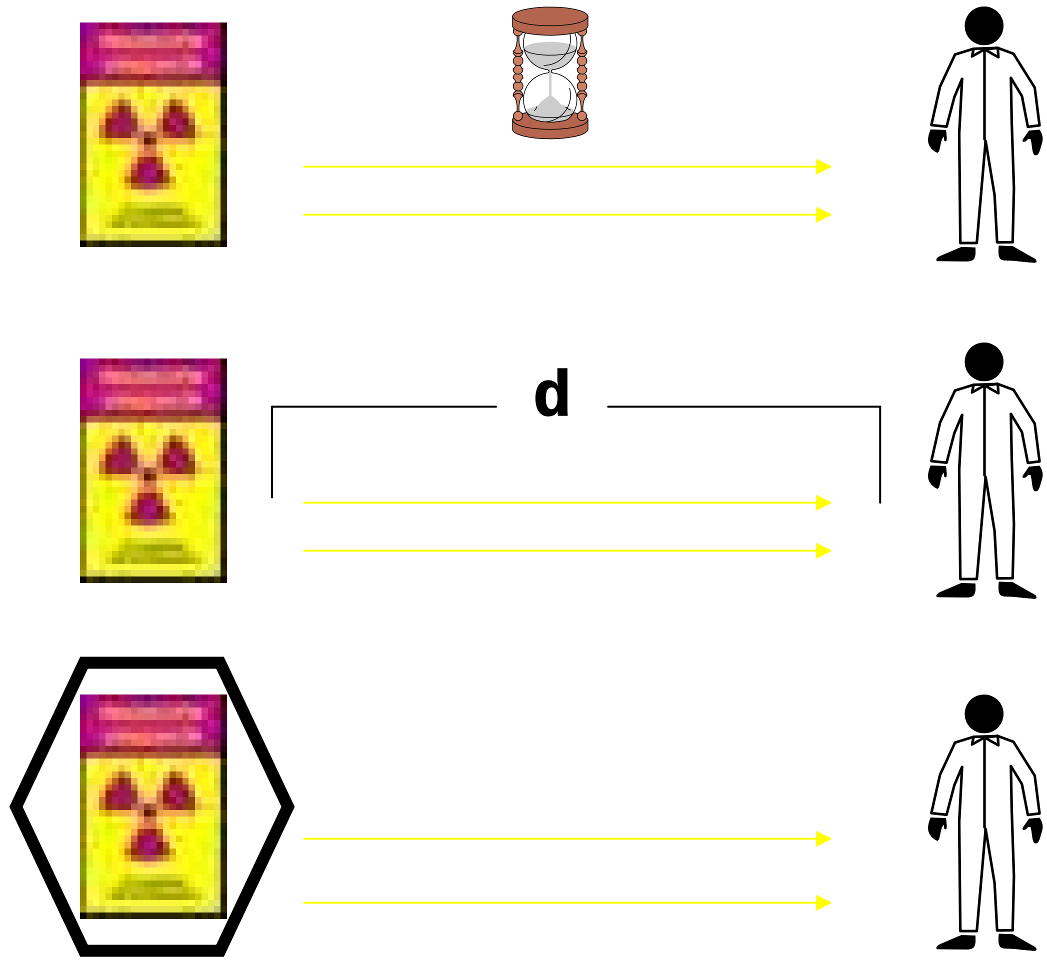
SÍNDROME DE IRRADIACIÓN:
Diarreas, Fiebres, Náuseas,Vómitos
Infecciones, Quemaduras con descamación seca o húmeda
Hemorragias intestinales

TÉCNICAS DE PROTECCIÓN RADIOLÓGICA

TIEMPO

DISTANCIA

BLINDAJE



Si la tasa de dosis de una fuente 370 MBq de 22Na a 50 cm es de 160 mGy/h, entonces a 100 cm será de 40 mGy/h y a 200 cm de 10 mGy/h.

Fíjese en que se recibe la misma dosis pasando 1 minuto a 50 cm de la fuente que en 16 minutos a 200 cm de dicha fuente.

En la manipulación de fuentes es común el uso de largas pinzas para aumentar la distancia de la fuente a la mano y al resto del cuerpo.