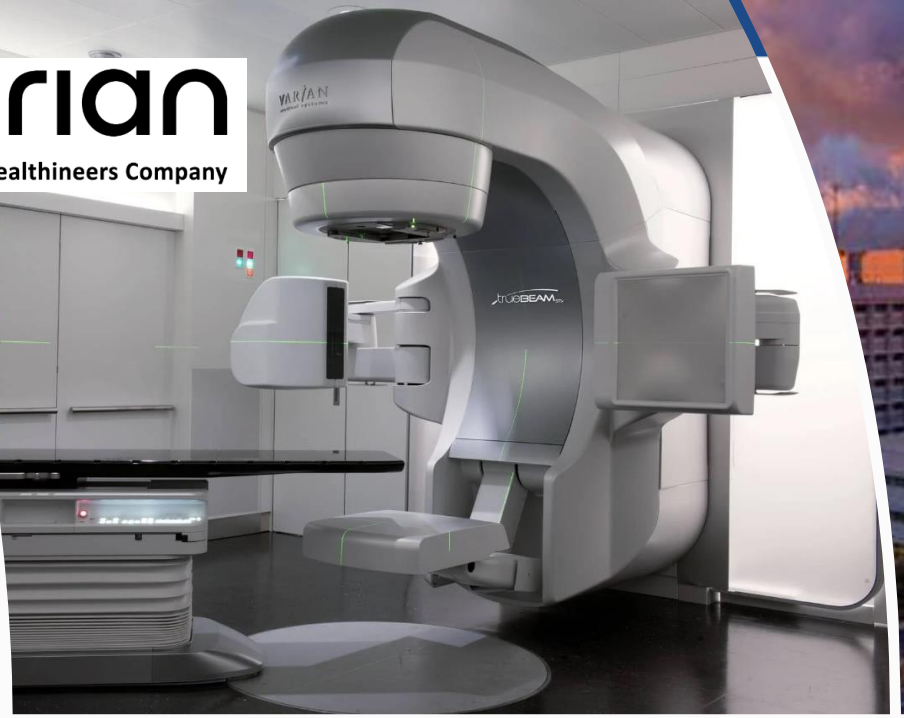
Ergonomics & Hygiene 2023

Collaboration for Sustainable Health in Future of Work

varian

A Siemens Healthineers Company



Alvin Gan

Credentials:

- Certified Safety Professional (CSP)
- Certified Industrial Hygienist (CIH)
- Advanced Radiation Safety Officer certificate (Australia's Nuclear Science & Technology Organization – ANSTO)

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Will Ionising Radiation turn me into

THE INCREDIBLE HULK ?

Fundamentals 101: Radiation Safety and Protection

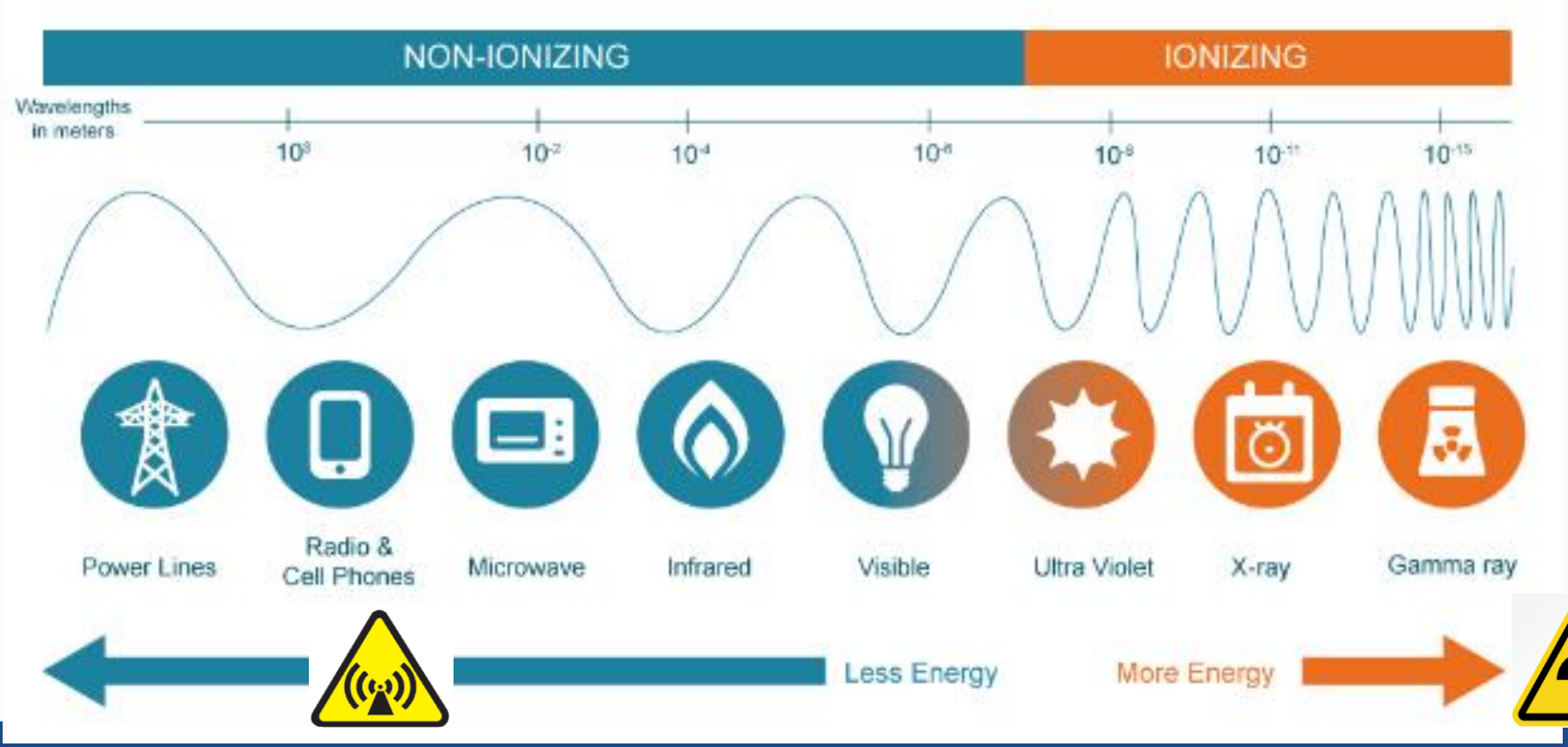
Credits: Marvel Comics

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Introduction on Radiation

Radiation

- **Non-Ionising Radiation**
- **Ionising Radiation**



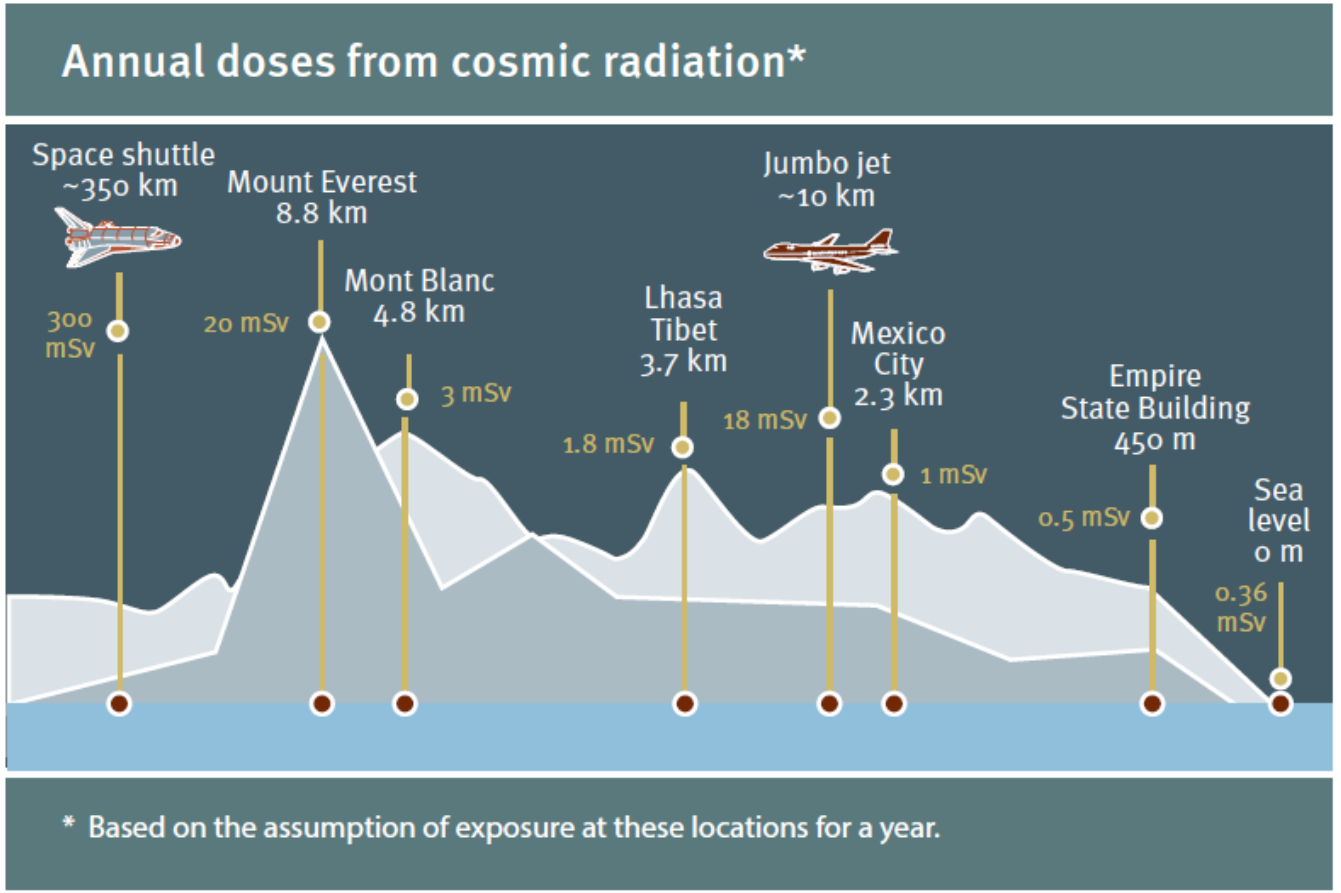
Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Sources of Radiation (Natural & Man-made)

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radiation Sources (Natural)

Credit:
https://www.env.go.jp/en/chemi/rhm/basic-info/1st/pdf/basic-1st-02-05-09.pdf

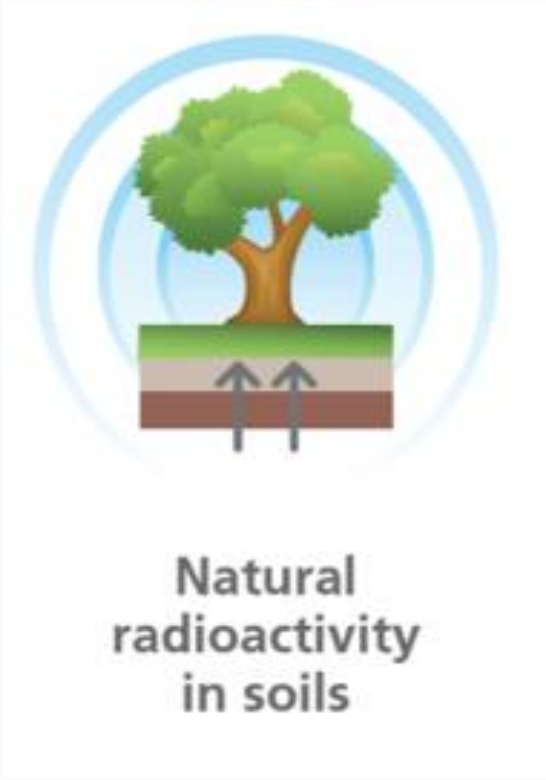


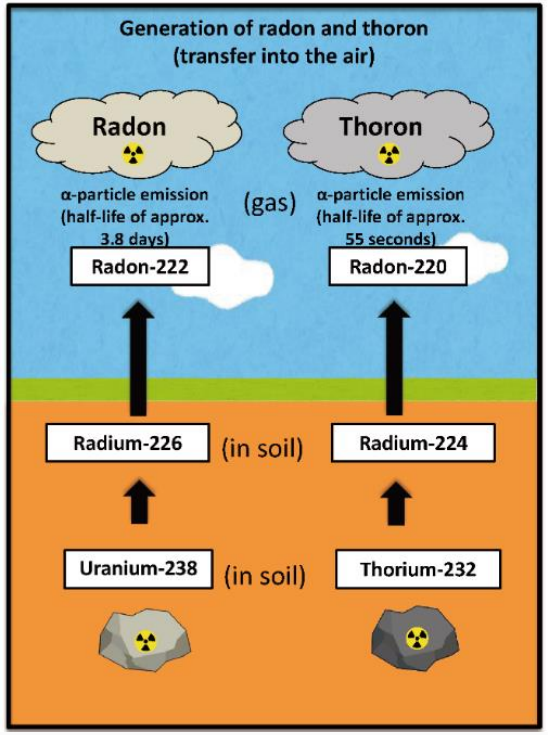
A 10-hour flight (New York–Paris round trip) would expose a person to about 0.05 mSv. (approx. equal to a routine chest x-ray)

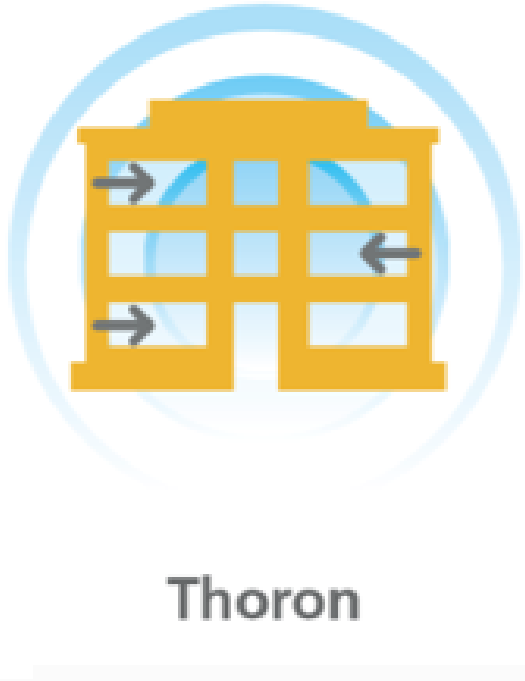
Source credit: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
https://www.unscear.org/unscear/en/publications/radiation-effects-and-sources.html

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radiation Sources (Natural)







NORM (Naturally Occurring Radioactive Material)

Credit: https://www.env.go.jp/en/chemi/rhm/basic-info/1st/pdf/basic-1st-02-05-09.pdf

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radiation Sources (Natural)

Bananas have naturally high-levels of potassium and a small fraction of all potassium (K-40) is radioactive.

Credit:
Mirion https://www.mirion.com/discover/knowledge-hub/articles/education/naturally-occurring-radiation-norm
US EPA
https://www.epa.gov/radtown/natural-radioactivity-food#:~:text=Like%20bananas%2C%20Brazil%20nuts%20contain,in%20which%20they%20are%20grown.

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radiation Sources (Man-made)

Medical radiation

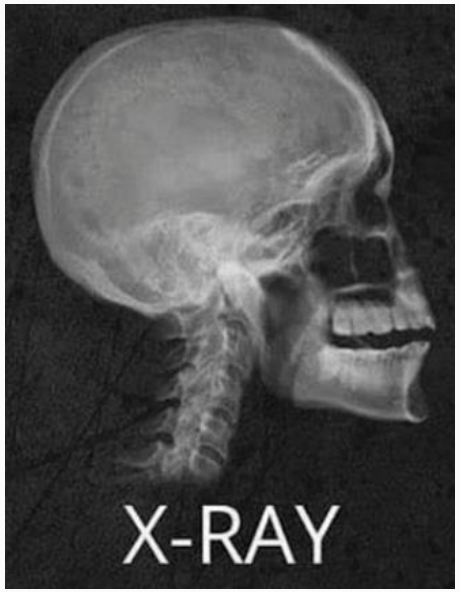
Workplace Radiation

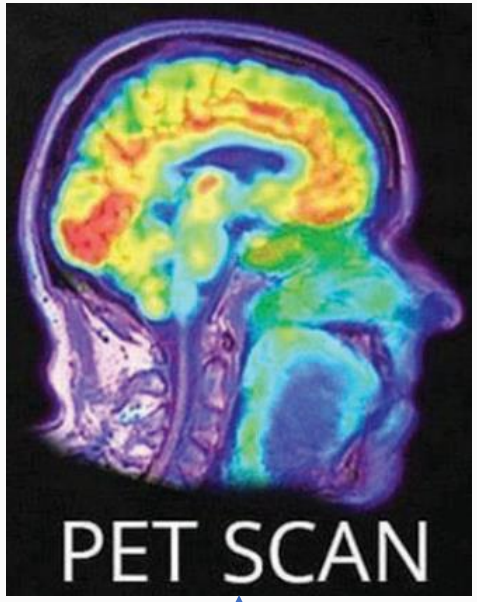
Radioactivity in the environment

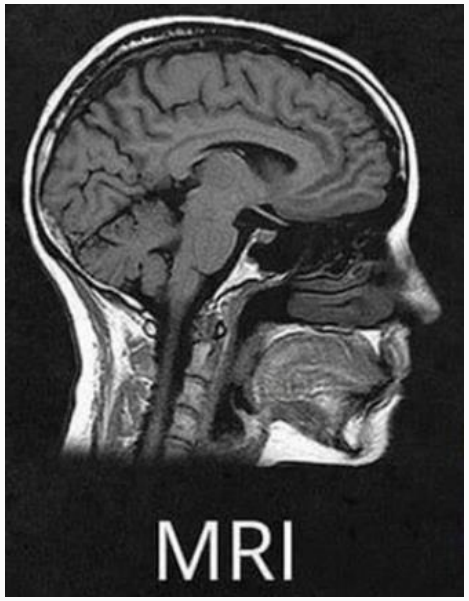
Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

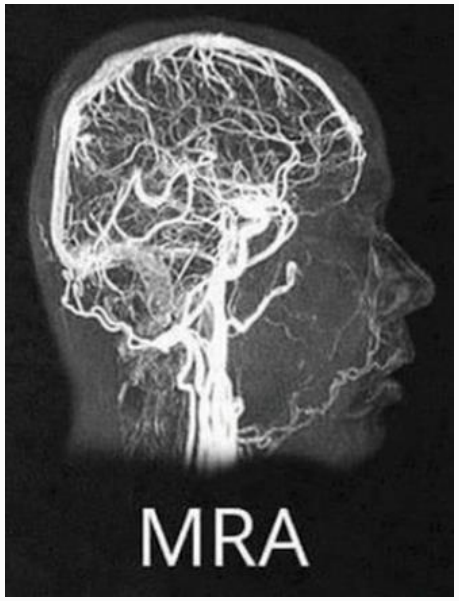
Medical Radiation

Example: Difference between the imaging scans (head)









Ionizing Radiation

Radiation exposure

Radioactive tracer is injected into the body

Non-Ionizing Radiation (Magnetic field)

No risk of radiation exposure

Image credits: Michael S. Tehrani, M.D.
https://sdbif.org/whats-the-difference-between-all-the-different-head-scans/

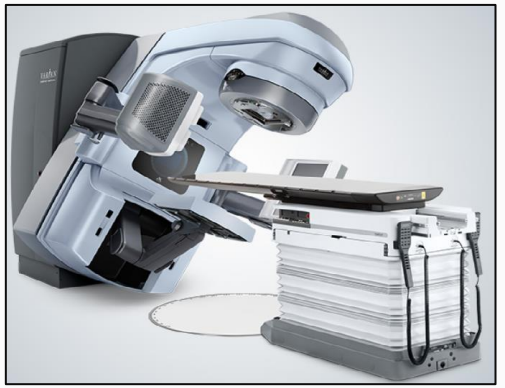
Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Workplace Radiation

Industrial Radiography with sealed source

Radiometric gauges (density, level etc) with sealed source

Nuclear Medicine/ Radiopharmaceuticals (unsealed source)



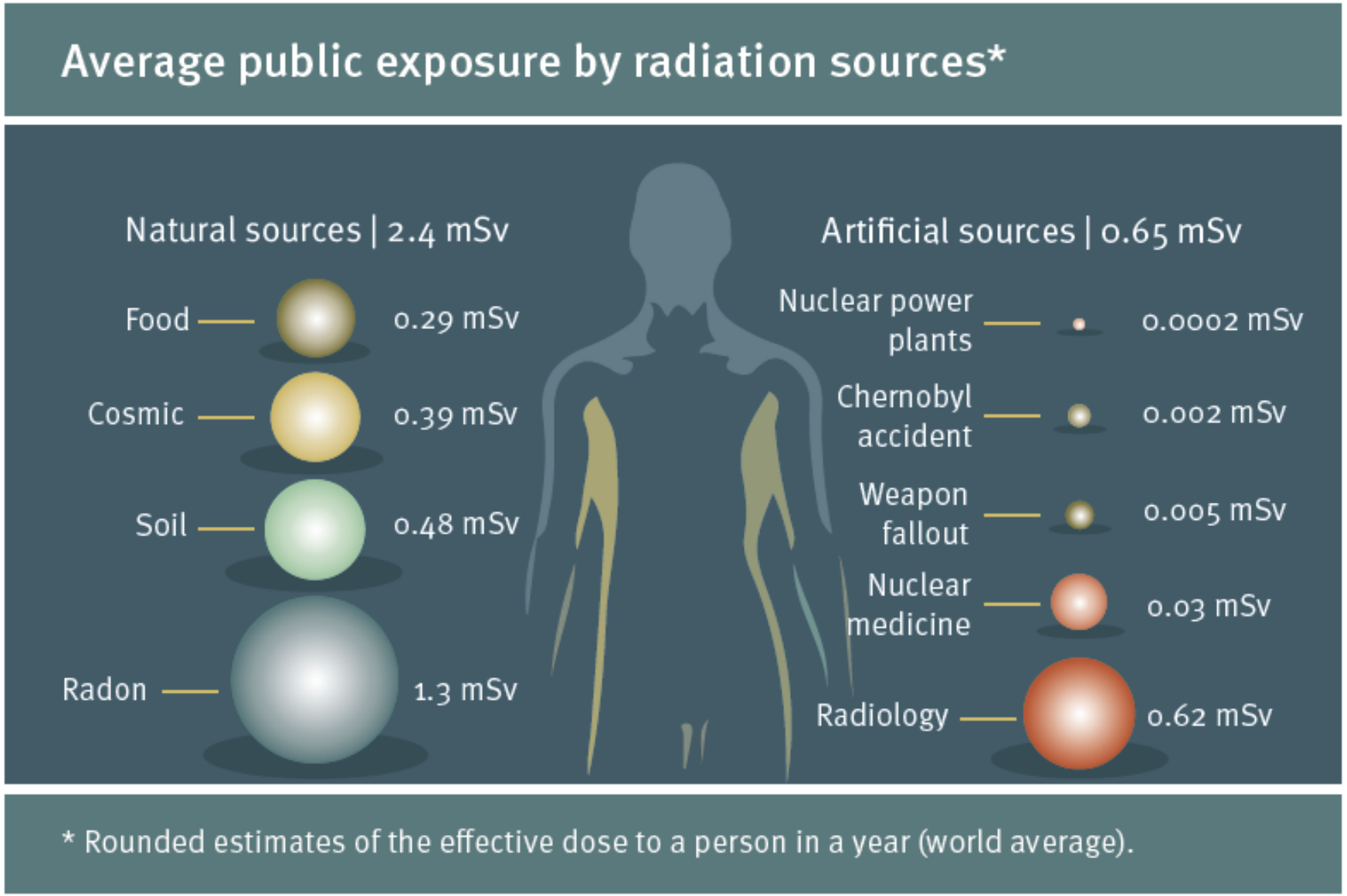
Linear Accelerator – Photon (X-ray), Proton, Electron (External Beam Radiation Therapy)

X ray imaging machines – Tomography, Fluoroscopy, Radiography

X-ray irradiator

X-Ray Fluorescence (XRF) Equipment

High Dose Rate (HDR) Brachytherapy afterloader (sealed sources)



Source credit: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
https://www.unscear.org/unscear/en/publications/radiation-effects-and-sources.html

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radiation Safety & Protection Regulatory Governance Framework

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Principal International Organizations

ICRP INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Founded 1928

IAEA International Atomic Energy Agency

Set up 1957

United Nations | Scientific Committee on the Effects of Atomic Radiation

Set up 1959

NCRP National Council on Radiation Protection and Measurements

Founded 1929
(US-centric)

DISCLAIMER: This is not an exhaustive list

National Environment Agency
Safeguard · Nurture · Cherish

Radiation Protection and Nuclear Science Group (RPNSG)

BADAN PENGAWAS TENAGA NUKLIR
BAPETEN

Republic of the Philippines
Philippine Nuclear Research Institute
Department of Science and Technology
ISO 9001:2015 Certified

VARANS
VIETNAM AGENCY FOR RADIATION AND NUCLEAR SAFETY

SHENA
S · A · F · E

اءوتوريتي كبغسأءن كسلامتن كصيحتن دان عالم سكيتر

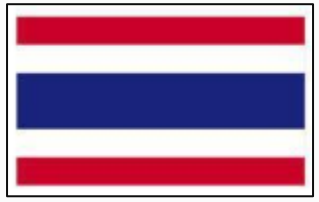
Safety, Health and Environment National Authority

DAE
Department Of Atomic Energy

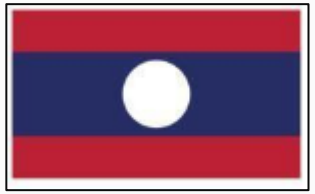
ELB
ATOMIC ENERGY LICENSING BOARD

JABATAN TENAGA ATOM

Ministry of Mines and Energy (MME)



สำนักงานปรมาณูเพื่อสันติ
Office of Atoms for Peace



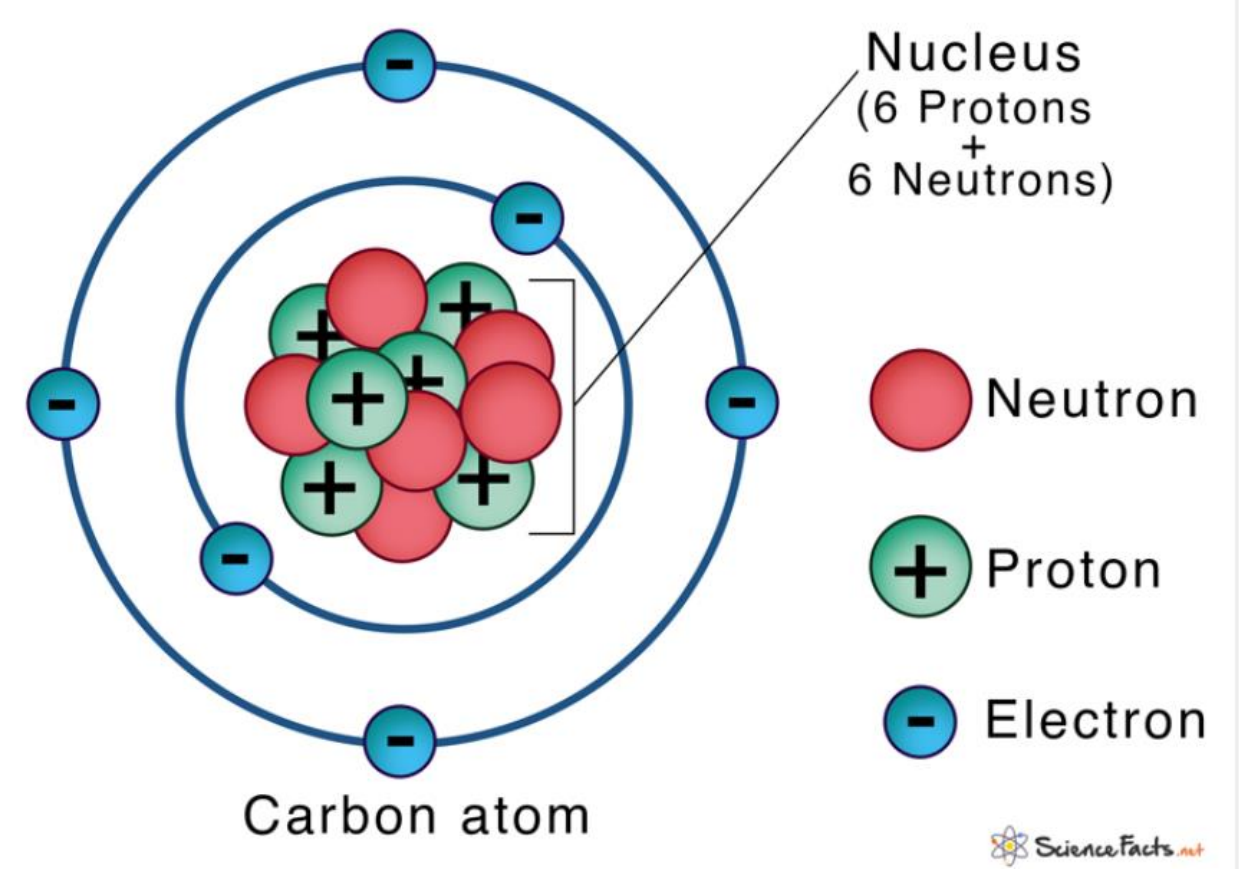
Ministry of Science and Technology - MOST (Dissolved as of March 2021)

https://laotiantimes.com/2021/03/01/government-of-laos-dissolves-ministry-of-science-and-technology/

DISCLAIMER: This is not an exhaustive list

What is Radioactive Material/ Radioisotope?

Structure of atom

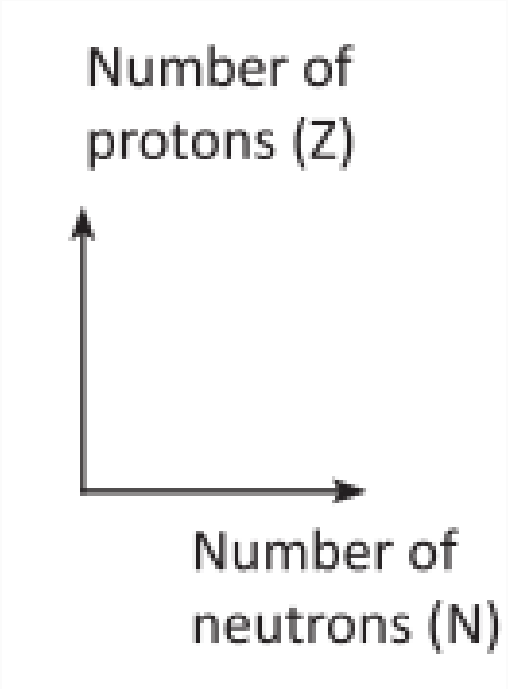


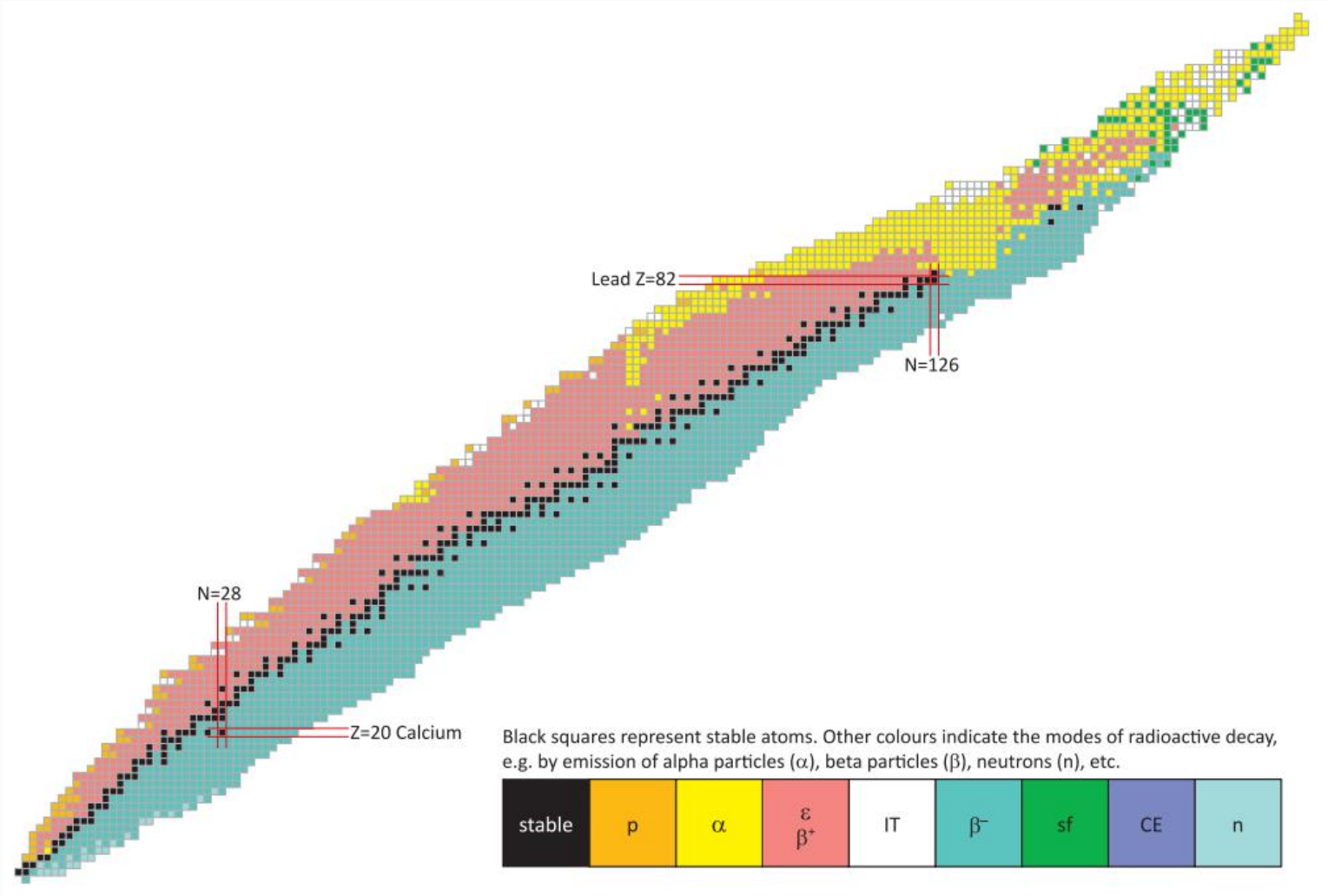
Carbon -12

No. of Protons **Z = 6**
No. of Neutrons **N =6**

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Chart of Nuclides

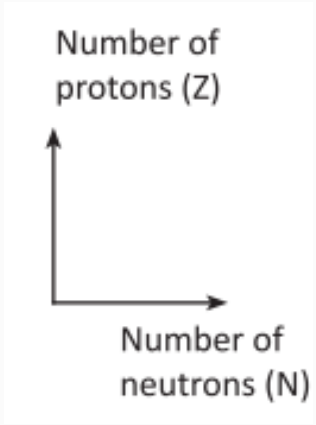


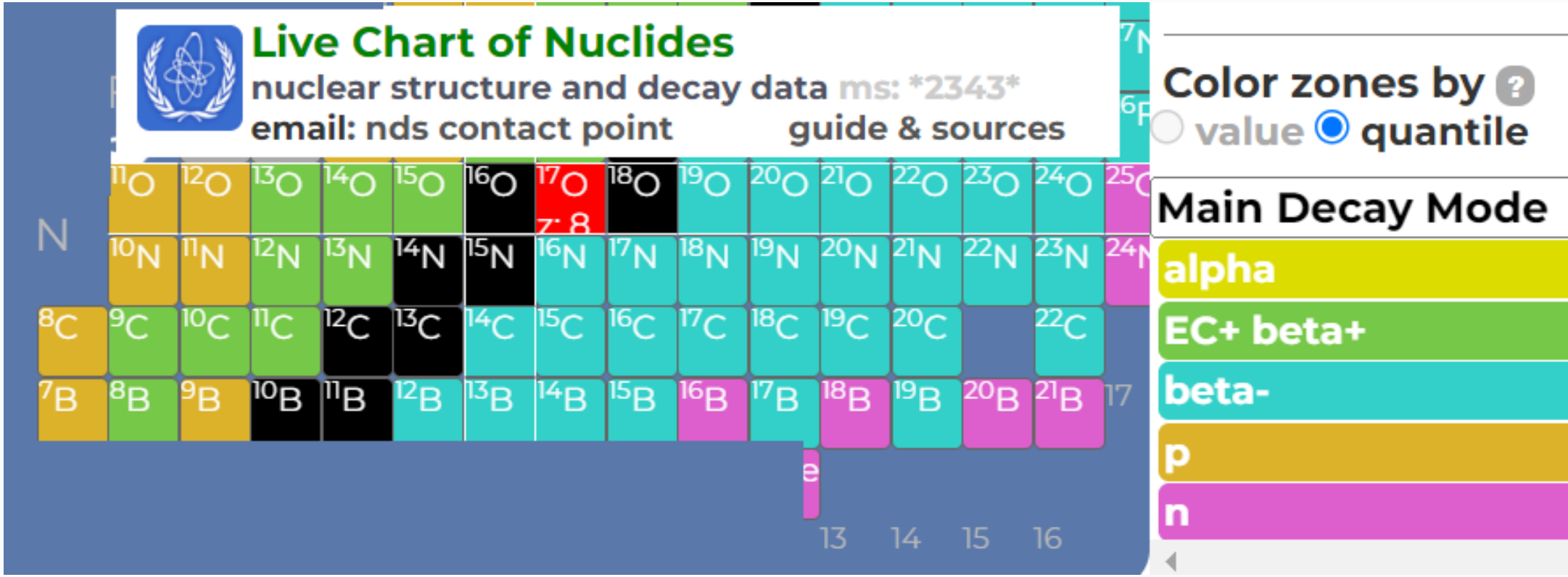


Source: https://www.epj-n.org/articles/epjn/pdf/2019/01/epjn180014.pdf

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

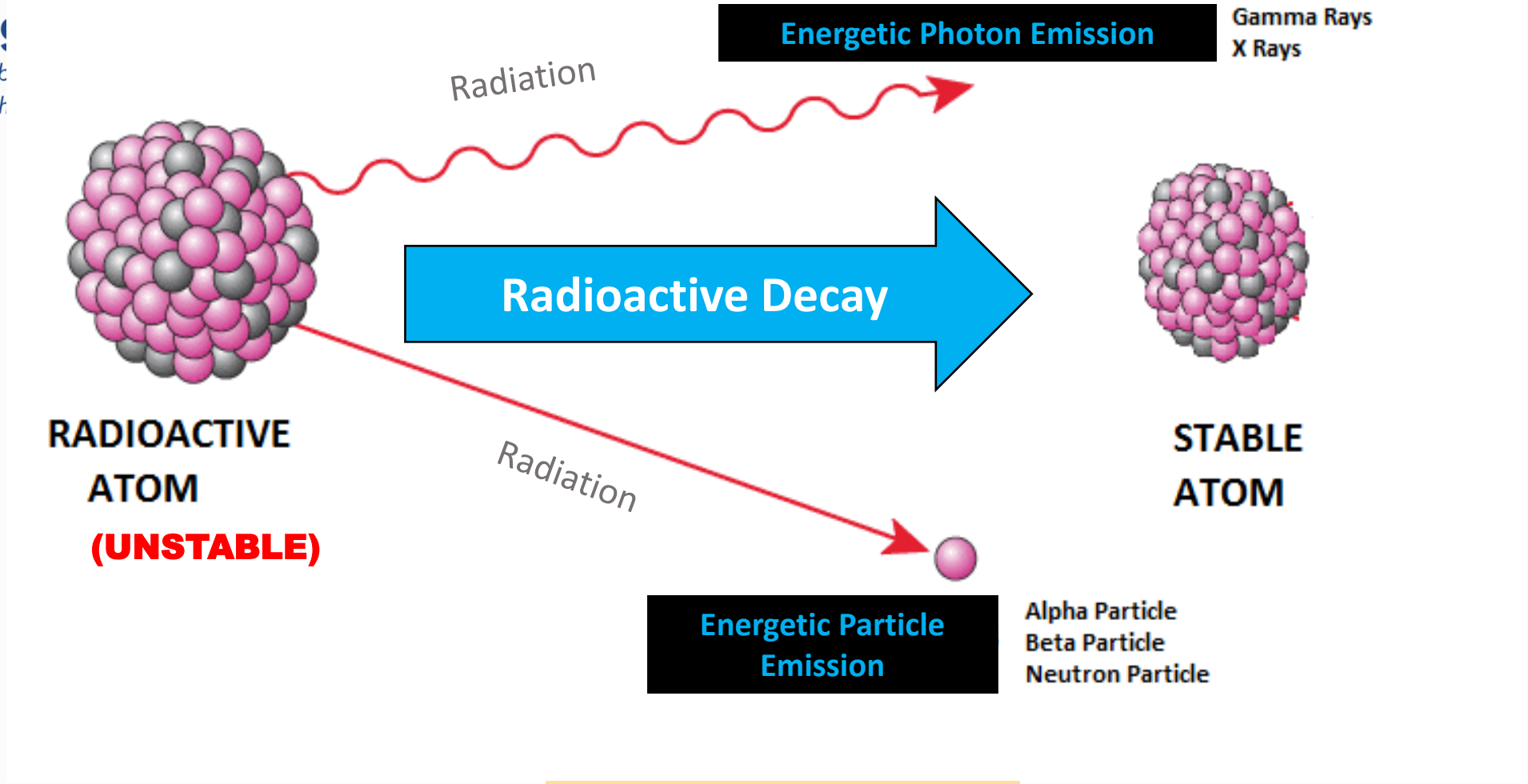
Chart of Nuclides (Radioisotope/ Radioactive)





Source: IAEA website (https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html

What is Radioactive Materials?

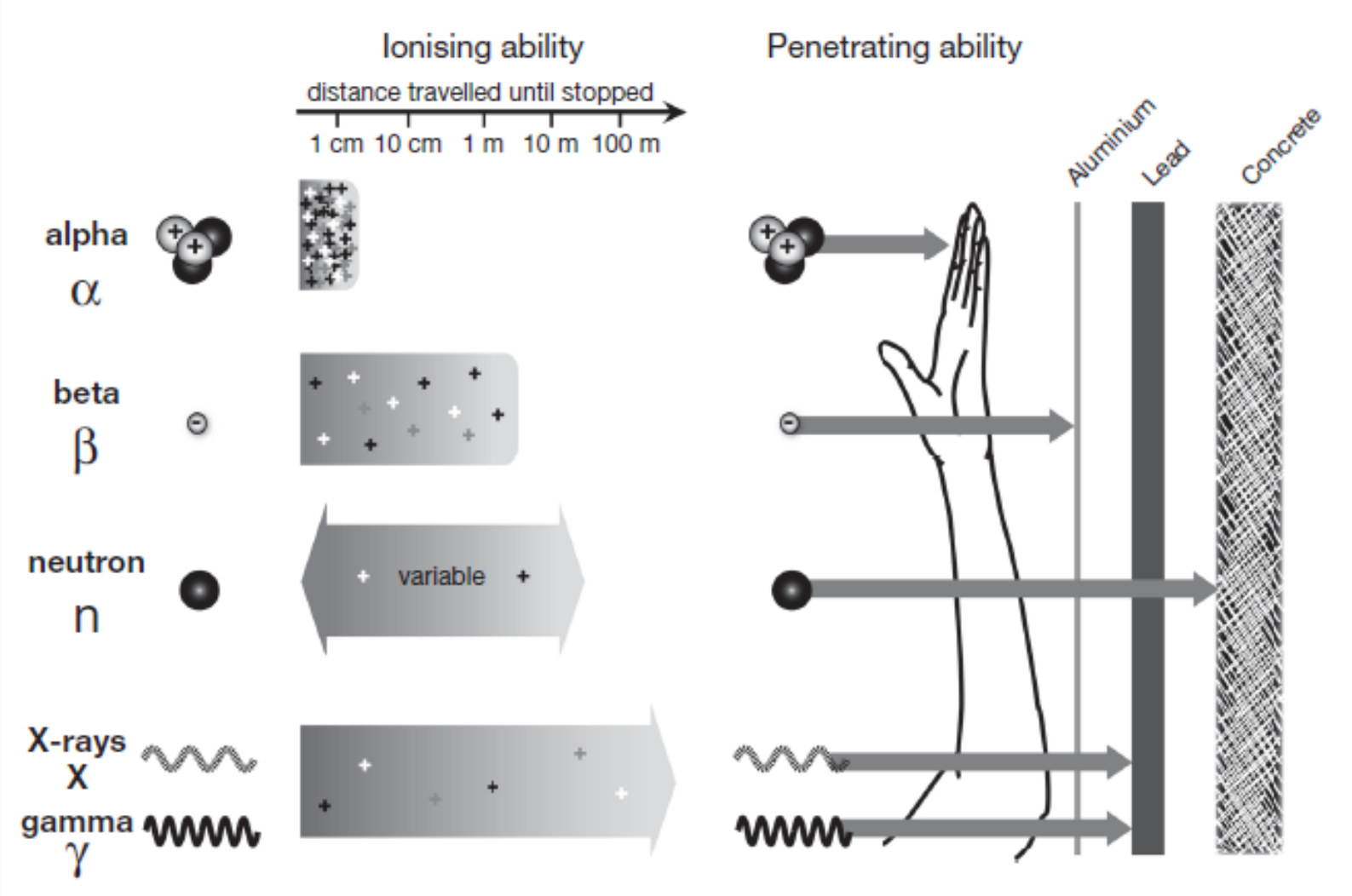


Ionizing Radiation

Sufficient energy to break chemical bonds and/or remove electrons from atoms

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Ionising ability/ Penetrating ability



Radiation Measuring Units

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Measuring Radiation

- There are four different but interrelated units for measuring radioactivity, exposure, absorbed dose, and dose equivalent. These can be remembered by the mnemonic **R-E-A-D**, as follows:

- **R**adioactivity
- **E**xposure
- **A**bsorbed dose
- **D**ose equivalent (or effective dose)

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Measuring Radiation

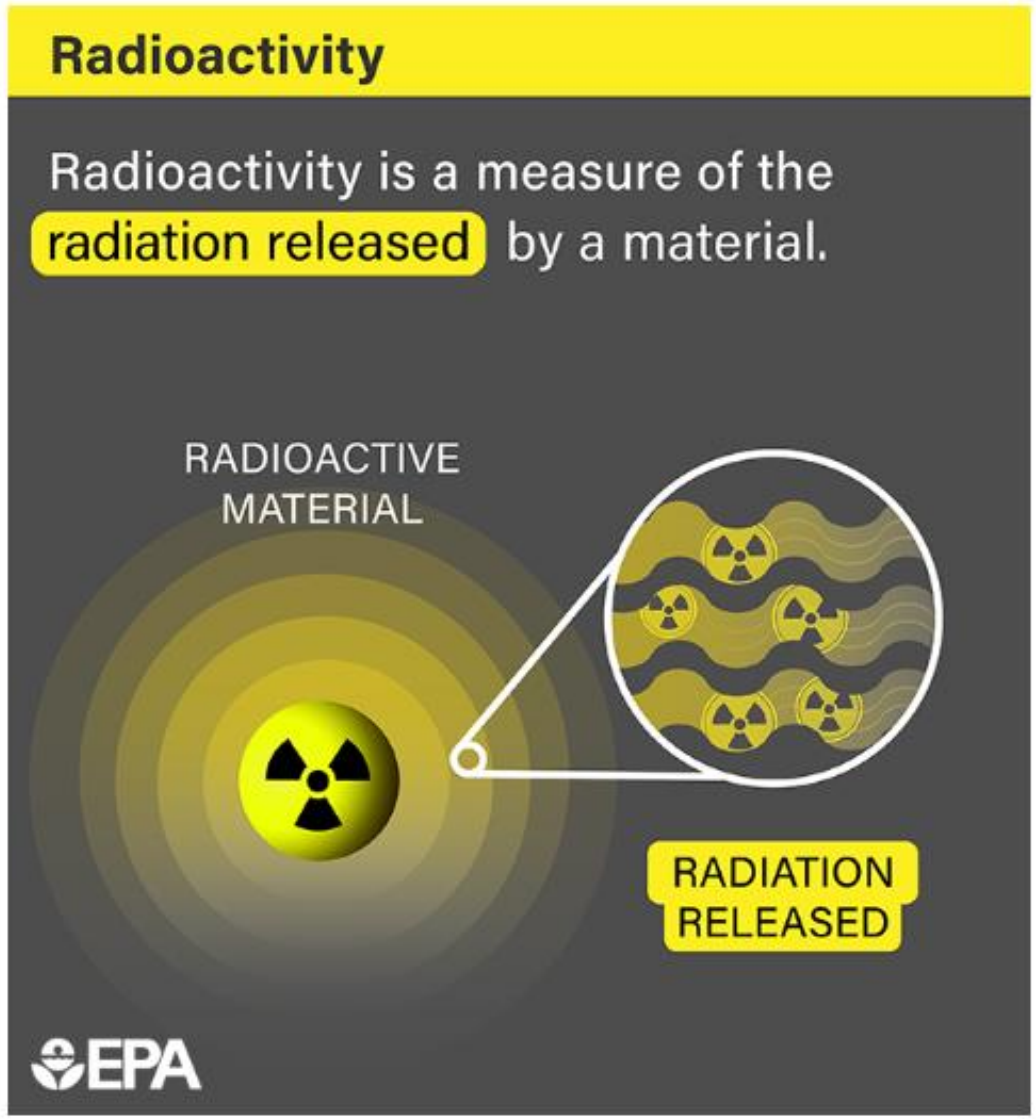
- **Radioactivity**
  - ➢ The rate of ionizing radiation being released by a radioactive material
  - ➢ Represents how many atoms in the material decay in a given time period
  - ➢ Units of measure

SI Unit – **Becquerel (Bq)**

US unit – **Curie (Ci)**

1Bq = 1 disintegration/ second (1dps)

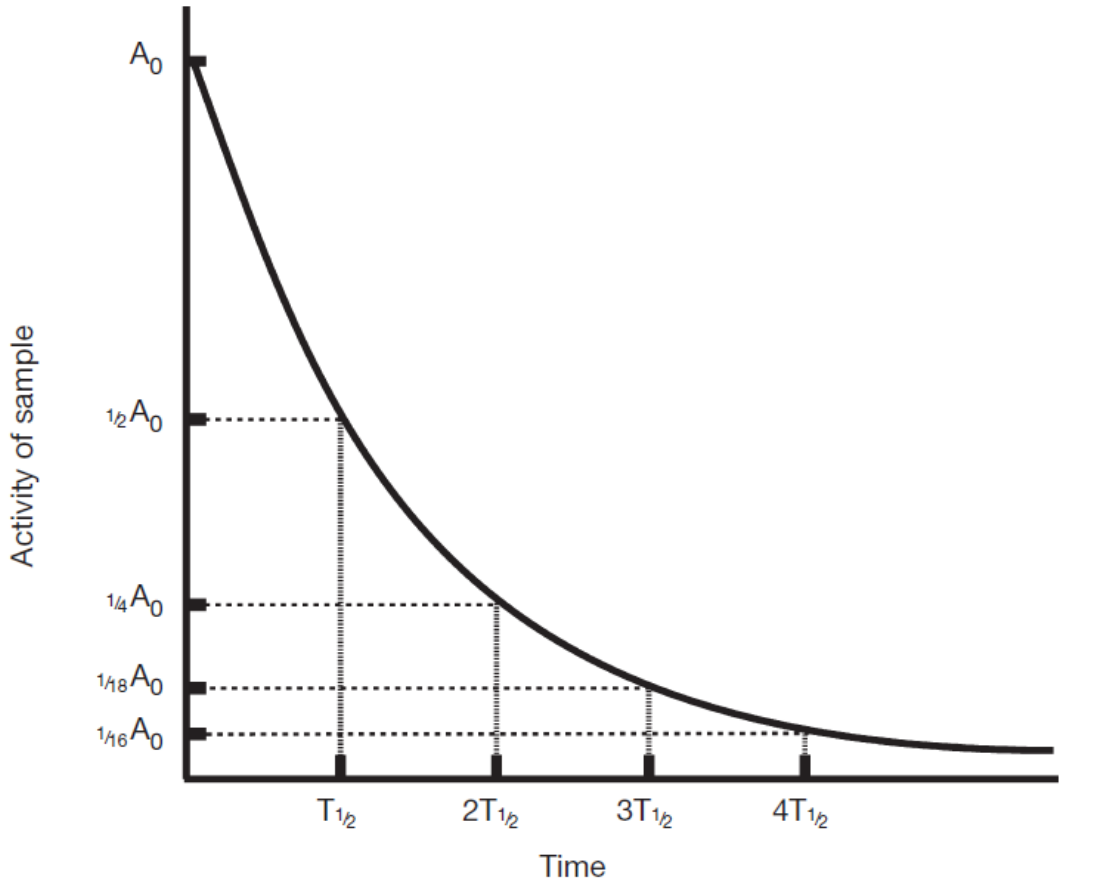
1 Ci = 3.7×10^{10} Bq



Credit: Radiation Terms and Units | US EPA

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radioactivity – Half Life



The pattern of radioactive decay

Radioactive decay is an exponential process and the Activity at time t can be calculated:

$$A = A_o/2^N$$

A_0 = Original Activity (Bq or Ci)
A = Activity at time t
N = the number of half lives completed in time, t ($N = t/T_{½}$)
$T_{½}$ = **Half-life**: the time for half of the unstable atoms to become stable.

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Measuring Radiation

- **E**xposure
  - the amount of radiation traveling through the air.
  - Many radiation monitors measure exposure
  - Units of measure

    SI Unit – Coulomb/kilogram (C/kg)

    US unit – Roentgen (R)

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Measuring Radiation

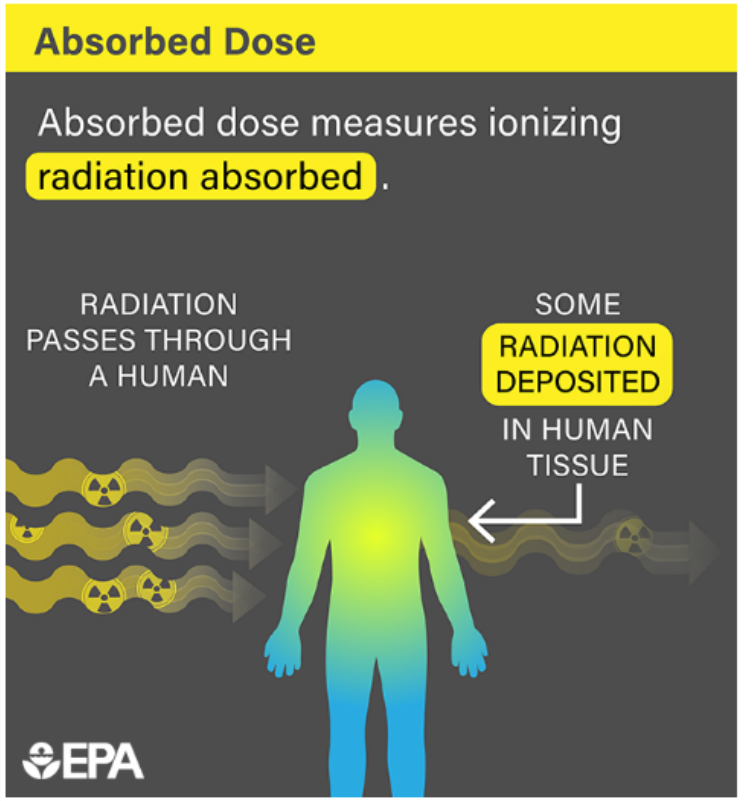
- **A**bsorbed dose
  - the amount of radiation absorbed by an object or person (that is, the amount of energy that radioactive sources deposit in materials through which they pass).
  - Units of measure

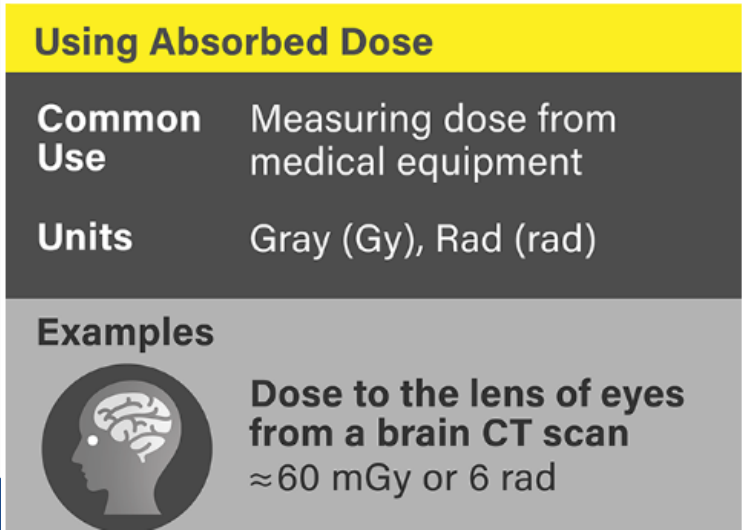
    SI Unit – Gray (Gy)

    US unit – radiation absorbed dose (rad)

    1 Gy = 100 rads

Credit: Radiation Terms and Units | US EPA



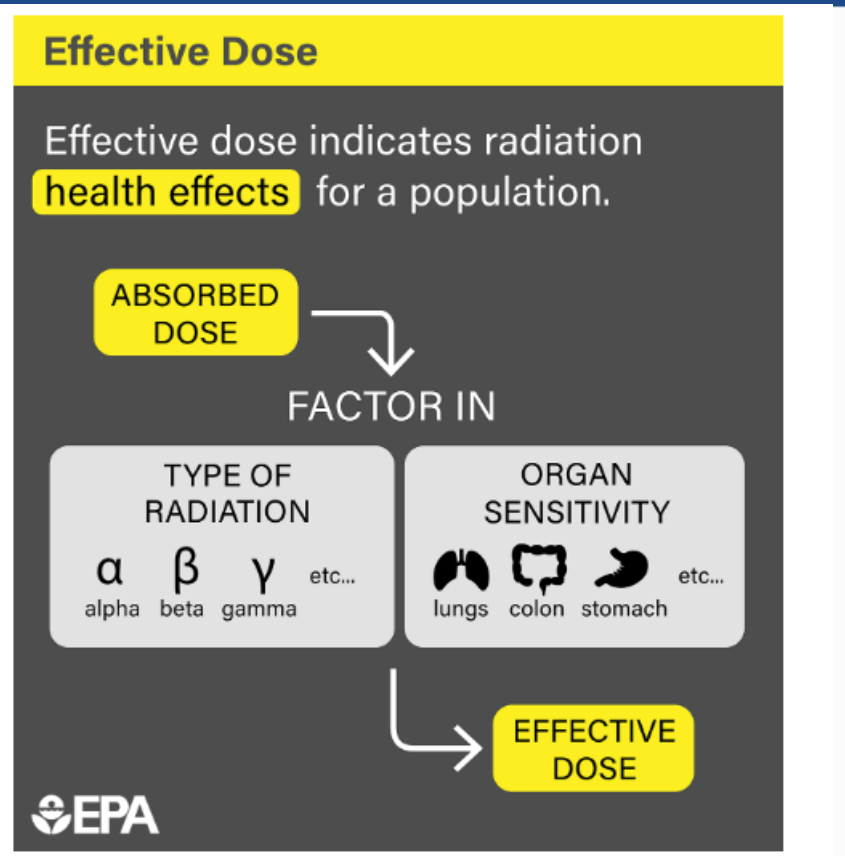


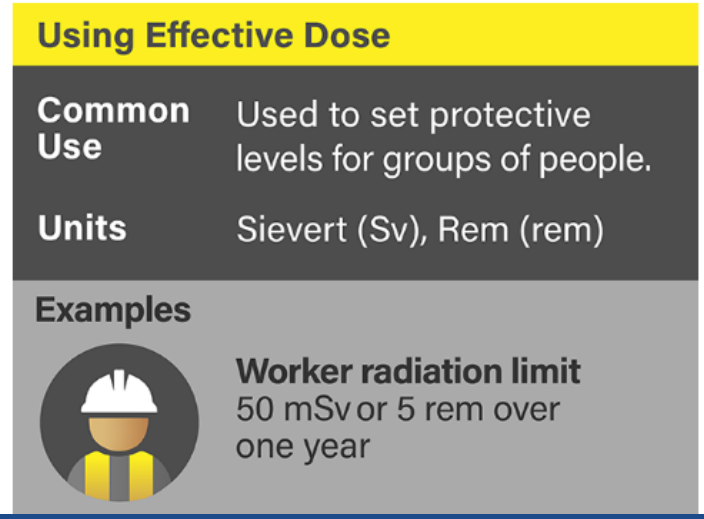
- **Dose equivalent (or effective dose)**
  - Measure the absorbed dose, but also takes into account the biological effectiveness of the radiation, which is dependent on the radiation type and energy.
  - Units of measure

    SI Unit – Sievert (Sv)

    US Unit – Roentgen equivalent man (rem)

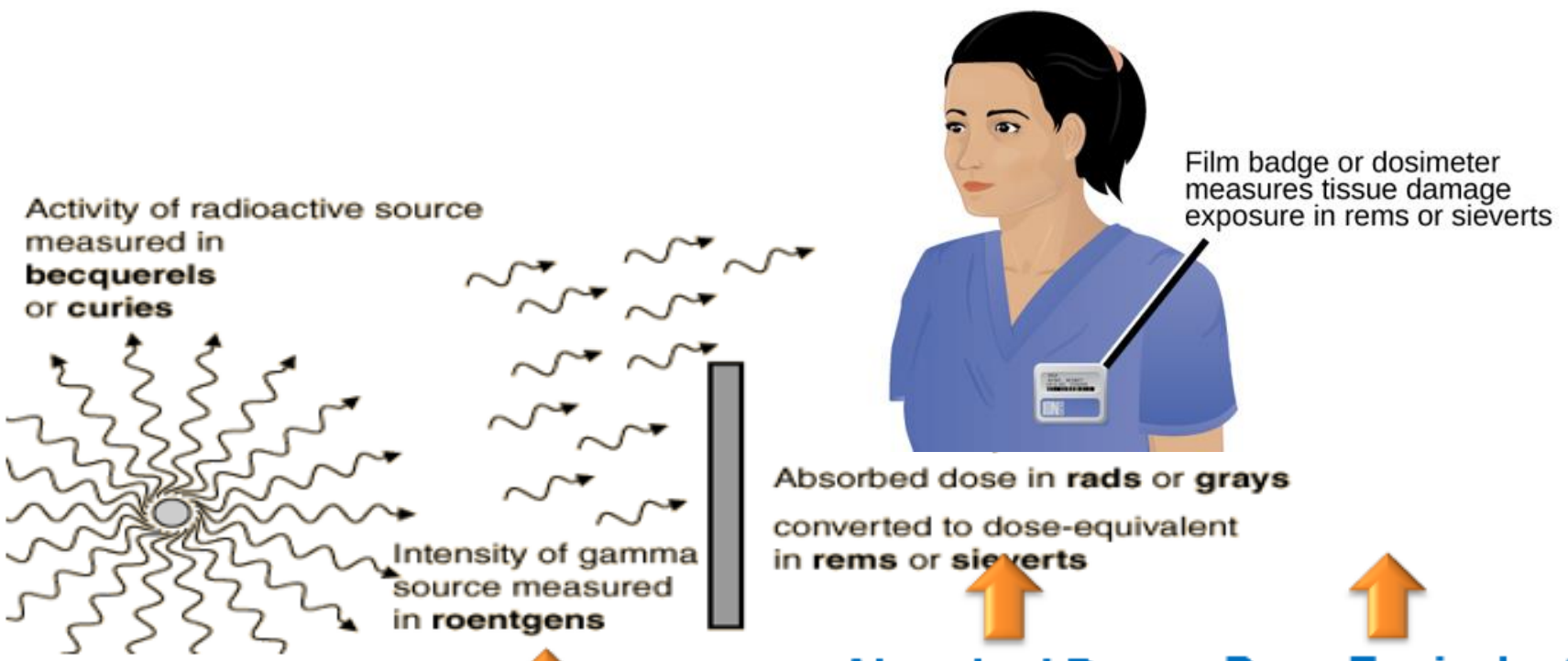
1 Sv = 100 rem





Credit: Radiation Terms and Units | US EPA

Measuring Radiation



Radioactive Source (Bq or Ci)

Exposure (Roentgens or Coulomb/kg)

Absorbed Dose

Take into consideration of radiation weighting factor W_R

Dose Equivalent/ Effective Dose

Take into consideration of tissue weighting factor W_T

Human Body receives a **DOSE** from radiation **EXPOSURE**

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Measuring Radiation

Radiation Weighting Factor W_R

Type of Radiation	Radiation Weighting Factor, W_R
beta	1
alpha	20
x-rays	1
γ-rays	1
neutrons < 10 keV	5
neutrons (10 keV – 100 keV)	10
neutrons (100 keV – 2 MeV)	20
neutrons (2 MeV – 20 MeV)	10
neutrons >20 MeV	5

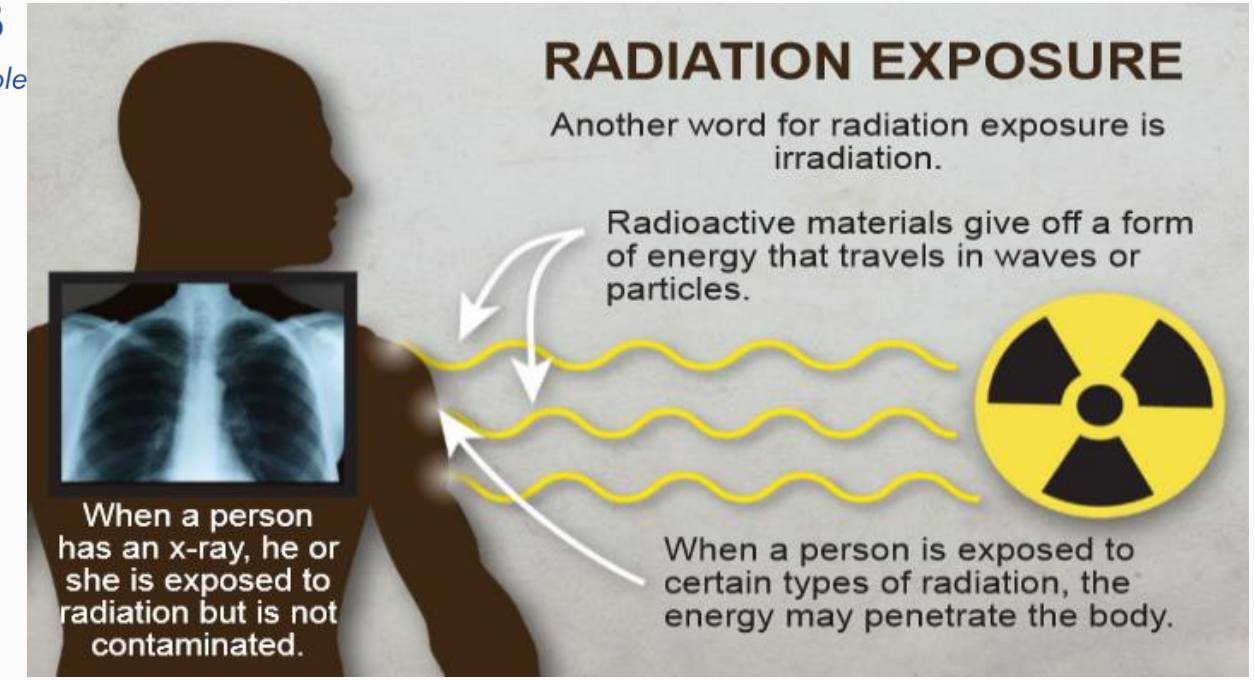
Tissue Weighting Factor W_T

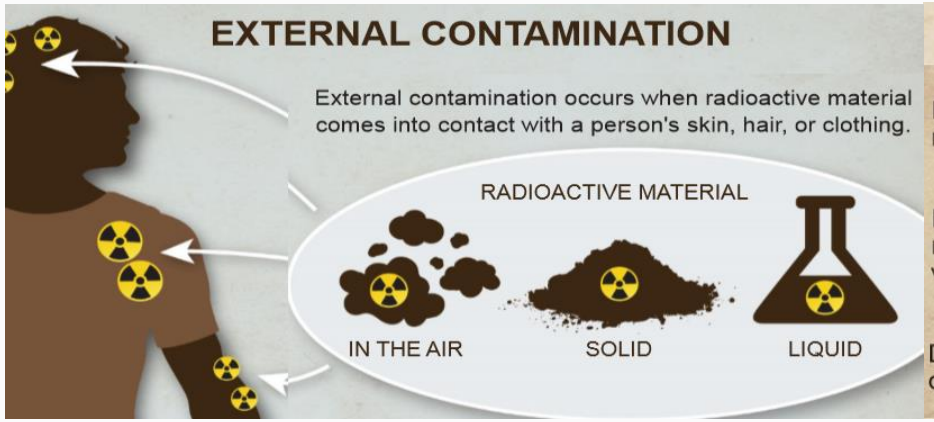
Tissue	W_T
Lung	0.12
Colon	0.12
Bone marrow	0.12
Stomach	0.12
Breast	0.12
Gonads	0.08
Bladder	0.04
Liver	0.04
Oesophagus	0.04
Thyroid	0.04
Skin	0.01
Bone Surfaces	0.01
Salivary glands	0.01
Brain	0.01
Remainder	0.12
Total (Whole body)	**1**

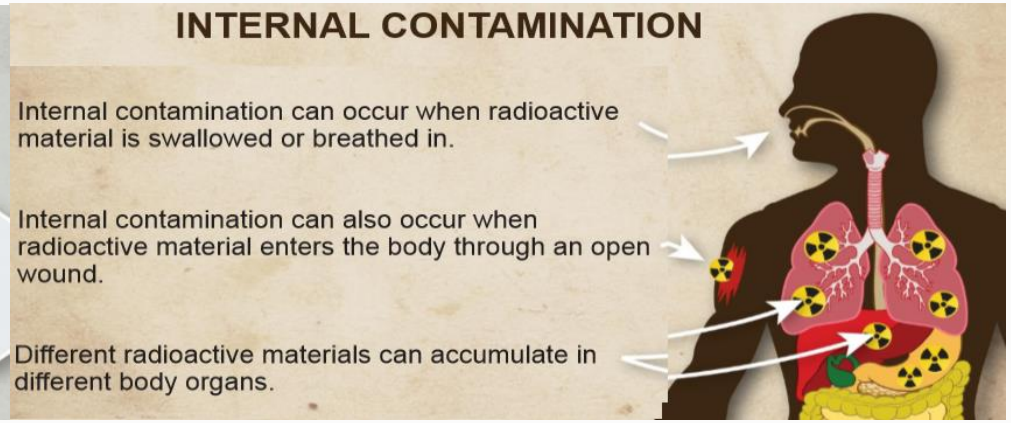
- Non-specialized cells that are rapidly cells (blood forming cells, cells lining in stomach) – less resistant to radiation
- Specialized and slow dividing cells (brain, muscle, nerve cells) more resistance to radiation

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Exposure vs Contamination







The body receives RADIATION DOSE in both cases (exposure or contamination)

Radiation Dose and Biological Effects

Biological Effects of Ionizing Radiation

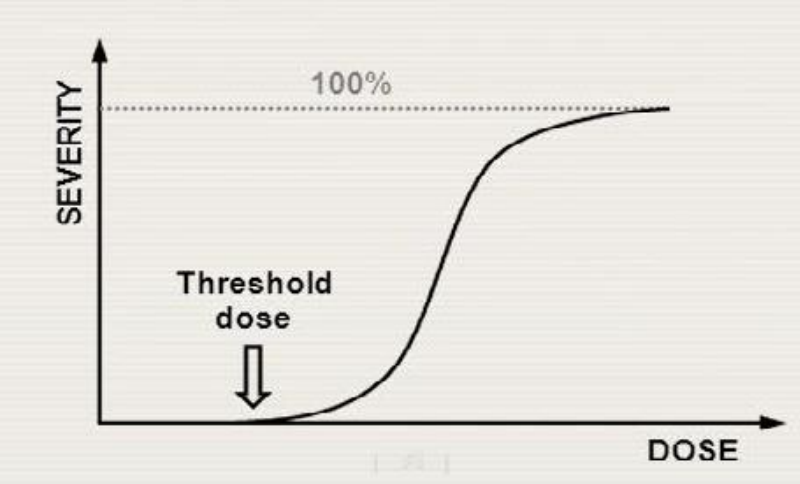
Credit: United States CDC website

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Biological Effects of Ionising Radiation

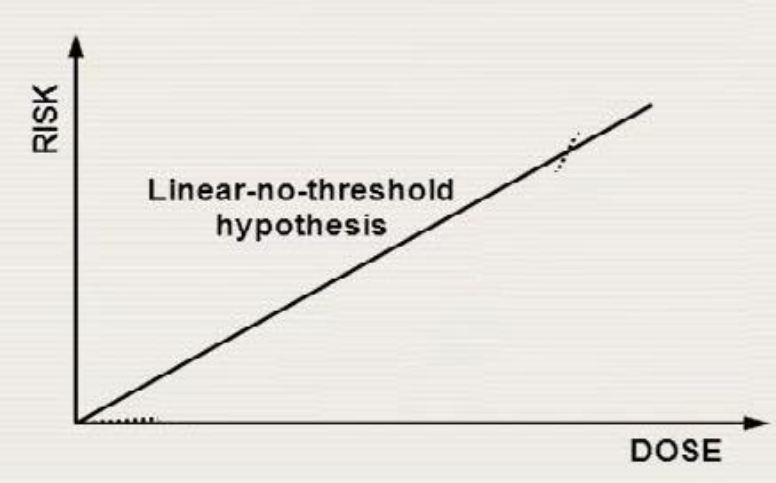
Deterministic effects (early health effects)

- Threshold Limit, above which effects are clinically observable
- Severity increases with dose
- E.g. Acute radiation sickness (ARS)/ radiation poisoning, nausea, skin reddening, sterility, and cataract formation



Non-deterministic/ stochastic effects (late health effects)

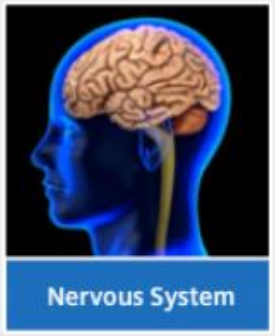
- No Threshold Limit
- Probability of occurrence increases with dose
- Severity is independent of dose
- Late effects, often decades after exposure
- E.g. Cancer, leukemia, and genetic changes



Radiosensitivity

Cell Sensitivity

Cells that are actively dividing are more sensitive to radiation, and are less able to repair damage. These include:

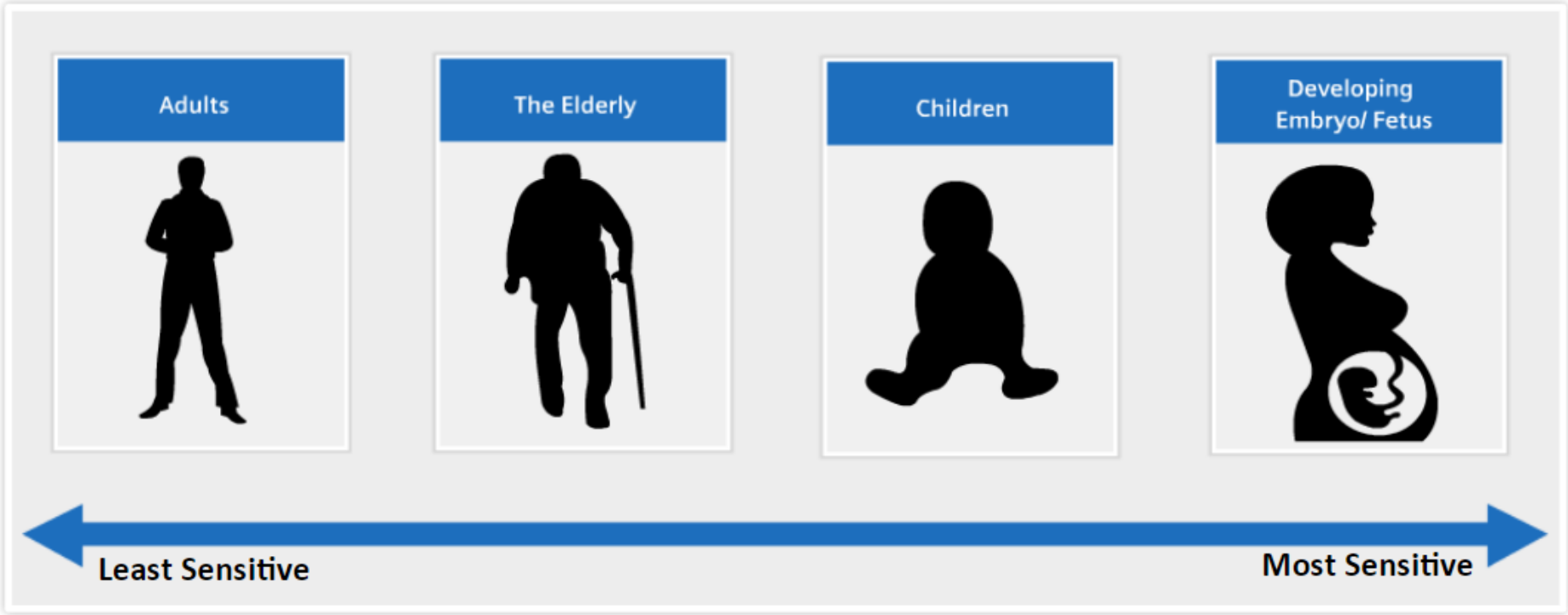


Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radiosensitivity

Individual Sensitivity

Some individuals are more sensitive to radiation than others.



Putting a scale to radiation dose

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Putting a scale to radiation dose

4 – 5 Sv Lethal dose with a 50% risk within 30 days (LD50/30)

2 Sv Severe Radiation Poisoning (Usually fatal)

1 Sv (1000mSv)

Radiation Dose 1 Sv:

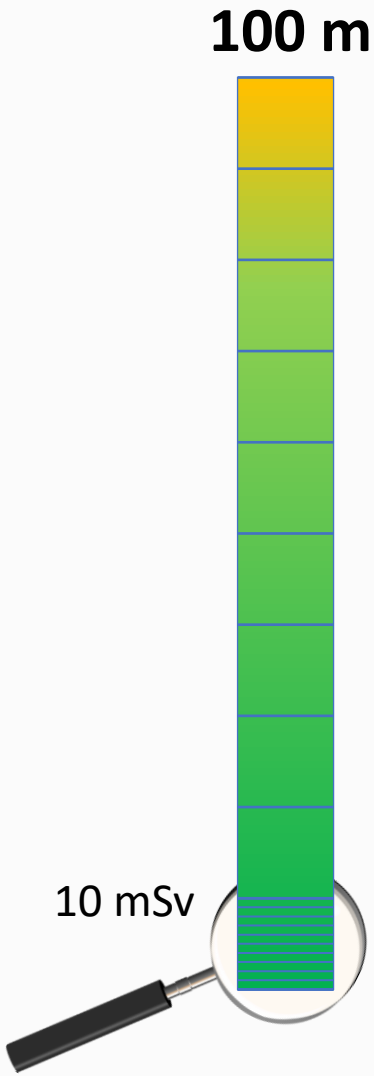
- High dose
- Increased risk of getting cancer (5%)
- Deterministic effects (Acute Radiation Sickness) – Not fatal
- Maximum allowed radiation exposure for NASA astronauts over their career

- Lowest yearly dose likely linked to increased cancer risk

Credit/ Source: https://xkcd.com/radiation/ & https://www.eenews.net/assets/2011/03/15/document_gw_03.pdf

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

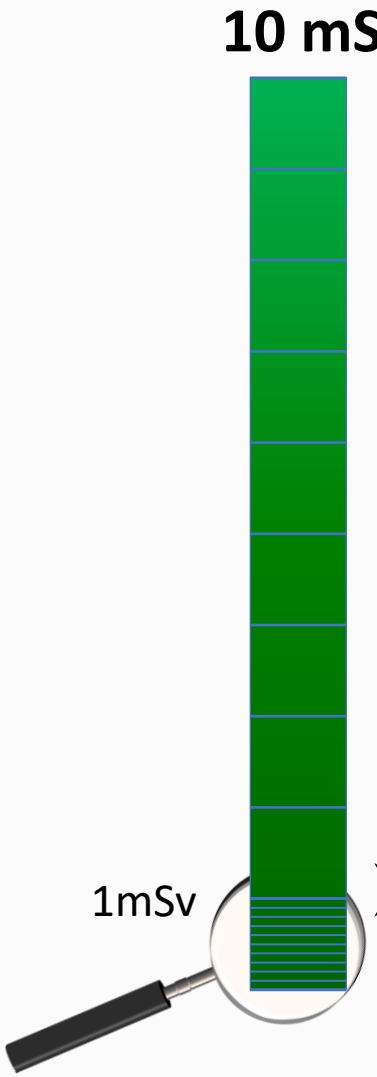
Putting a scale to radiation dose



- No significant increase in cancer risk below 100 mSv
- Natural background in some areas
- US annual dose limit 50 mSv
- NEA annual dose limit 20 mSv for radiation worker

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Putting a scale to radiation dose

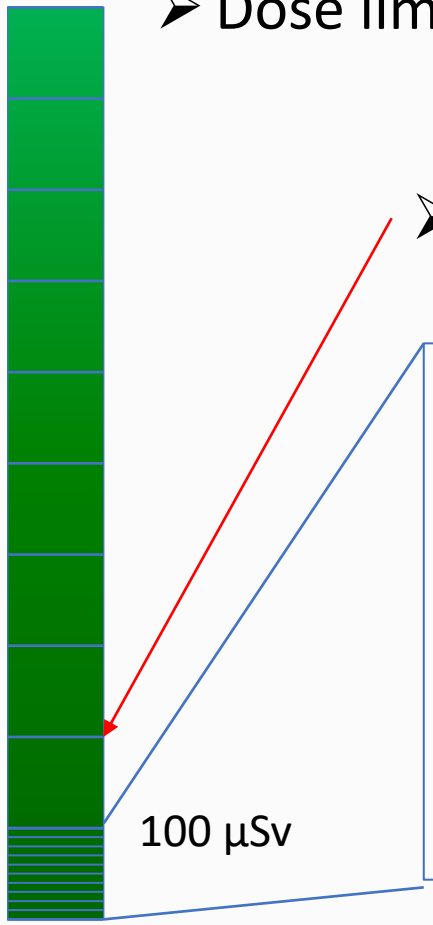


- CT scan 10 mSv
- Annual dose airline crew
- Annual dose by natural background 3 mSv
- **YOU ARE HERE**

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Putting a scale to radiation dose

1 mSv



100 µSv

- Dose limit for general public
- Yearly dose by potassium in the body

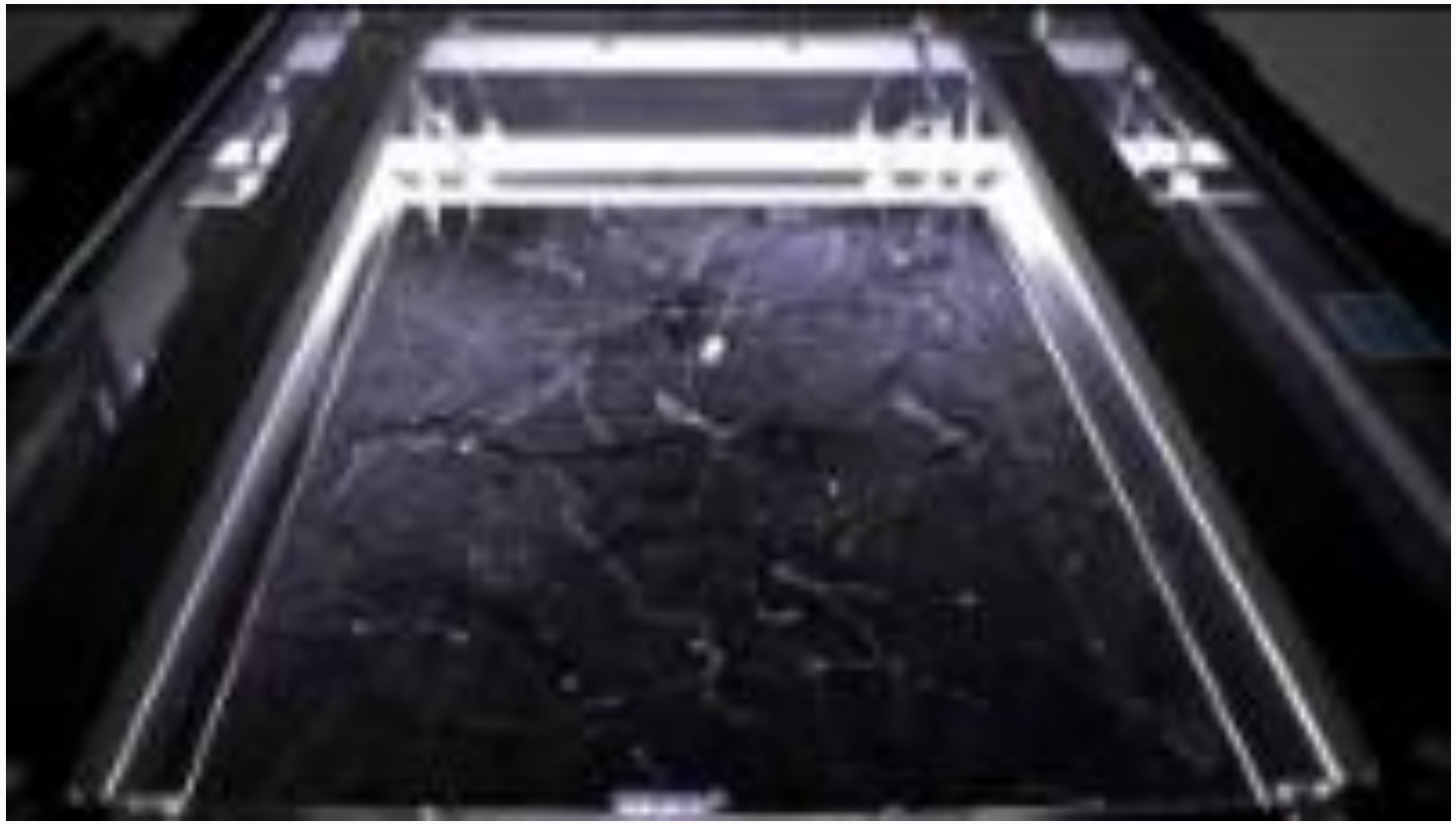
80 µSv – living in a solid house
75 µSv – flight FRA-SFO
40 µSv – additional dose to Tokyo after Fukushima
20 µSv – lung x-ray
10 µSv – daily dose by background radiation
1 µSv – using a CRT screen for a year
0.1 µSv – eating one banana (^{40}K)
0.05 µSv - Sleeping next to someone

Sources: https://www.radiologyinfo.org/en/pdf/safety-xray.pdf

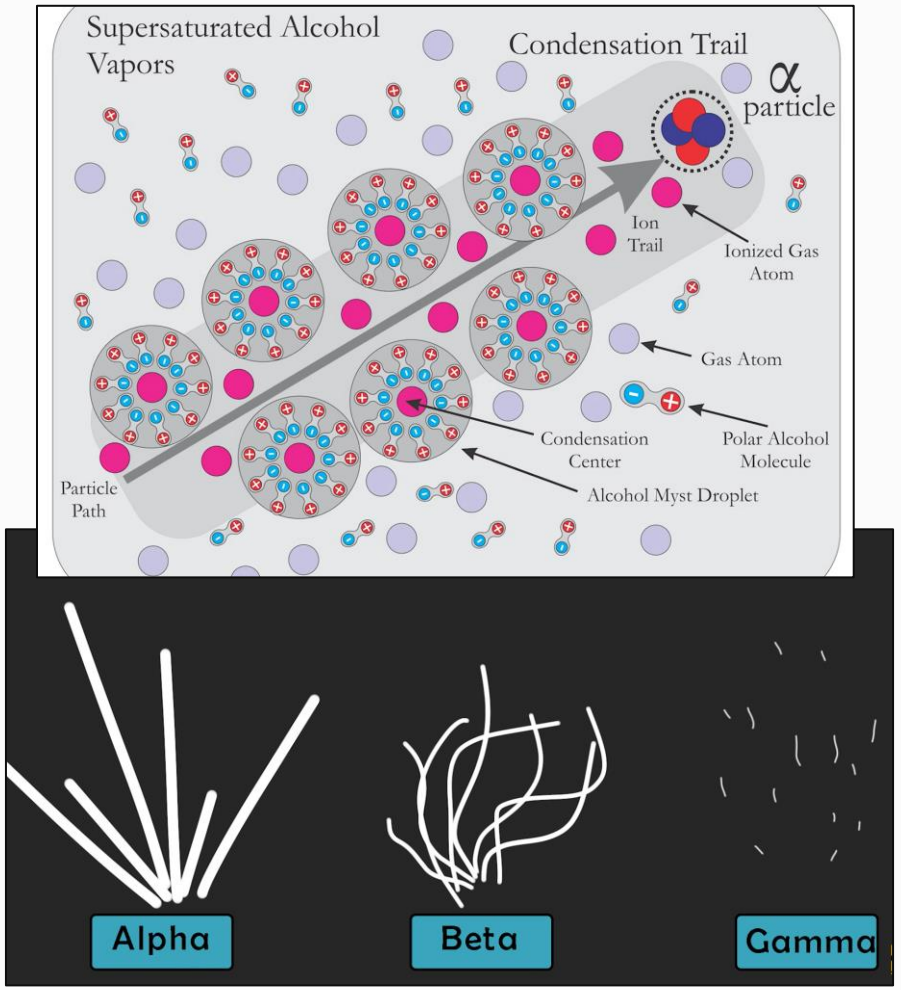
Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

How do you "see" radiation?

Only natural radioactivity (background)



Video credit: Nuledo Cloud Chambers
https://www.youtube.com/watch?v=i15ef618DP0

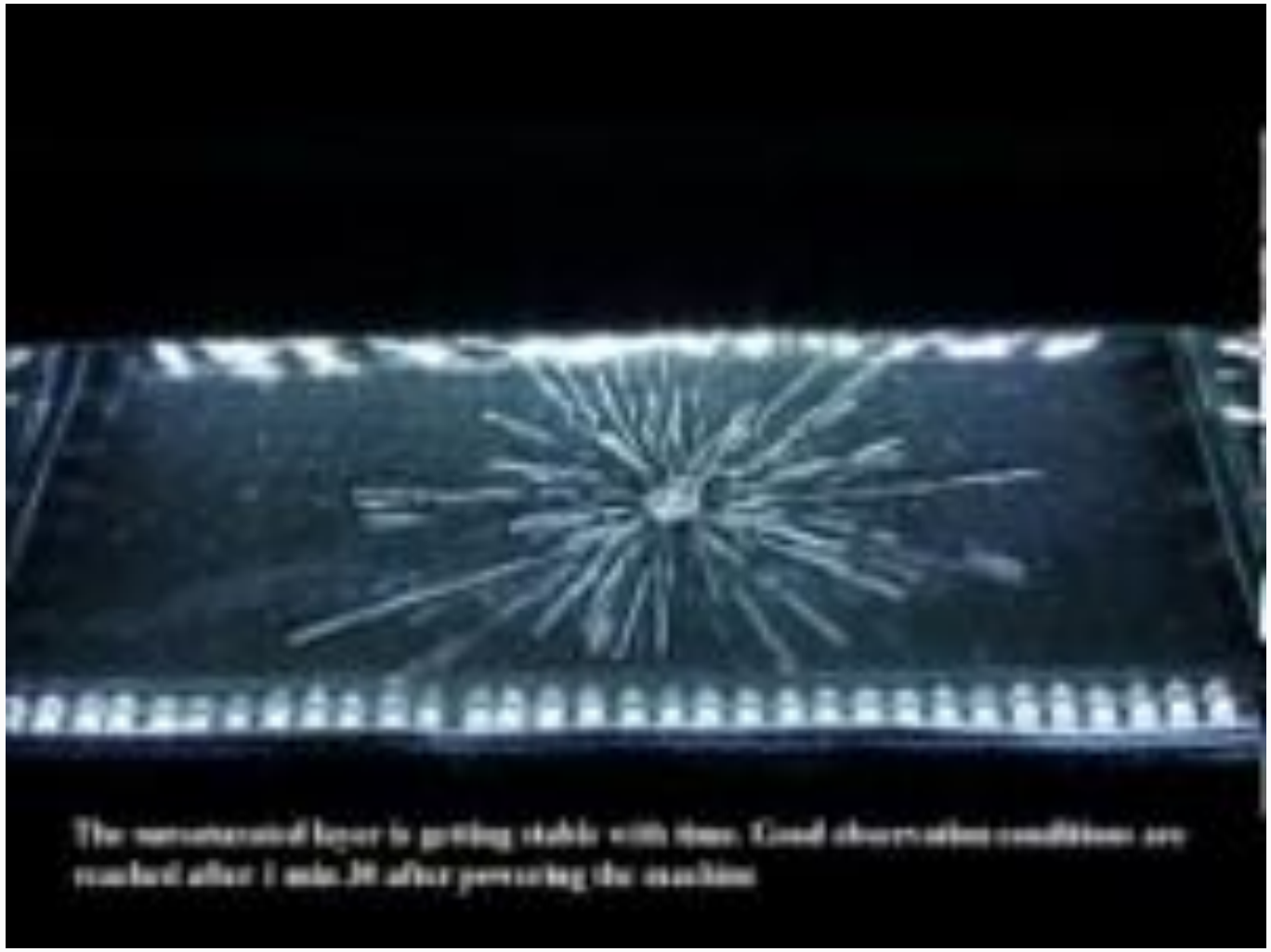


Picture credits: The Action Lab
https://www.youtube.com/watch?v=7VH9l4hgbII

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

How do you “see” radiation?

With radioactive material



Video credit: Cloudylab
https://www.youtube.com/watch?v=XGNvAEtYZkw

Radiation Detection/Monitoring

No single type of instrument can be used to detect or measure all types of radiation.

Radiation detection or measuring instruments are all based on one of four types of detector which, with associated electronic circuitry, may be used to indicate count rate, dose rate or accumulated dose:

- ionization chamber;
- proportional counter;
- Geiger–Muller tube;
- scintillation counter.

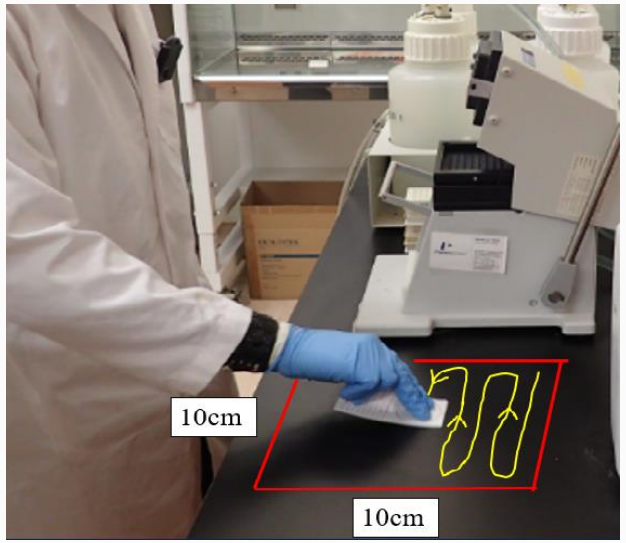
Ergonomics & Hygiene 2023

Collabor
Health in

Radiation Detection/Monitoring

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radiation Detection/Monitoring



Liquid Scintillation Counter

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

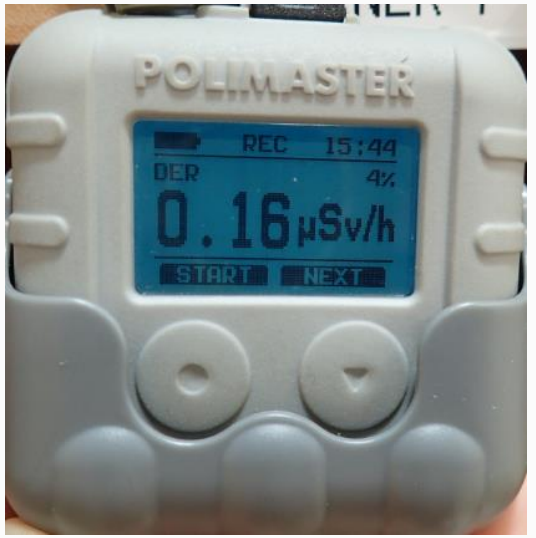
Personal Dose Monitoring

TLDs (Passive)

Whole Body Badge

Ring Badge

Electronic Personal Dosimeters (Active)

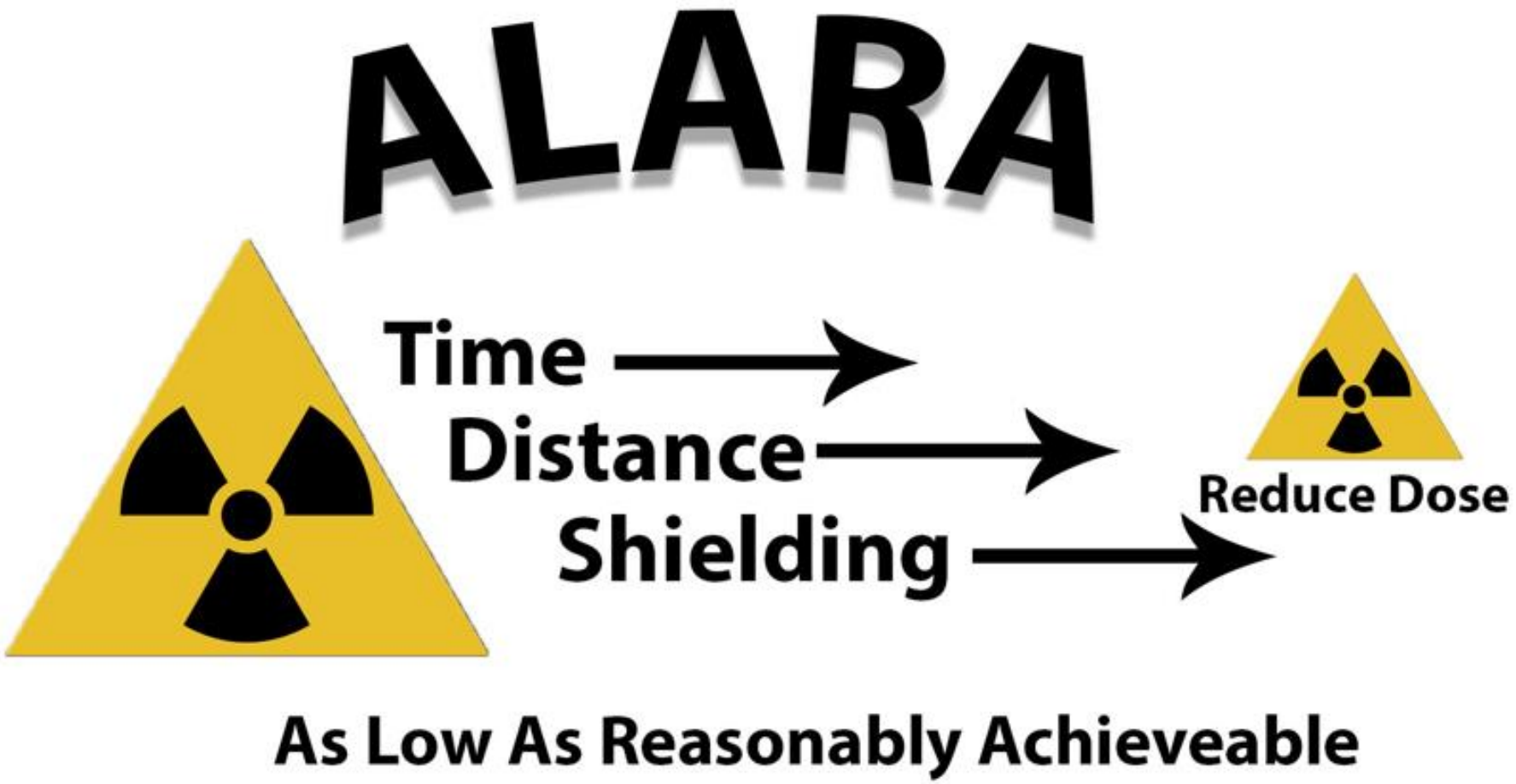


Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

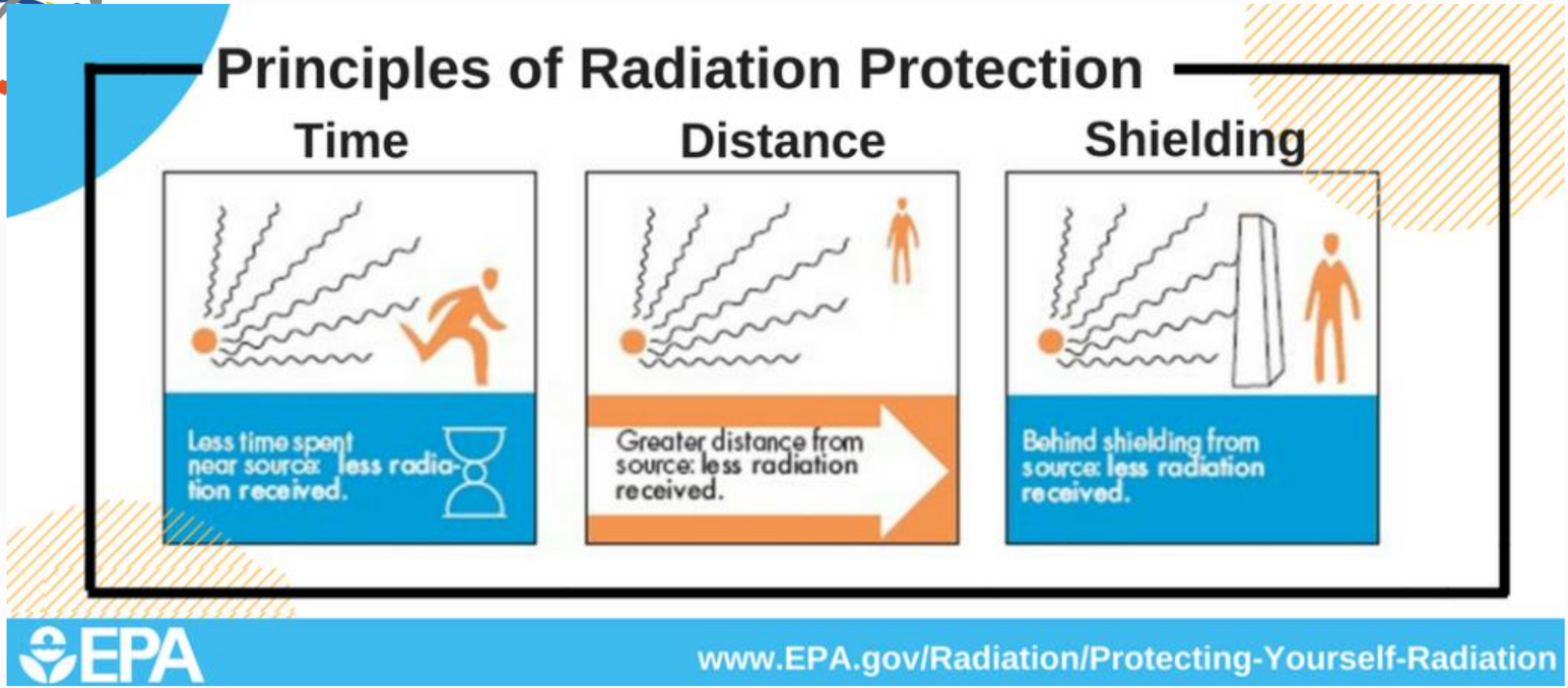
Radiation Safety & Protection

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Radiation Safety & Protection



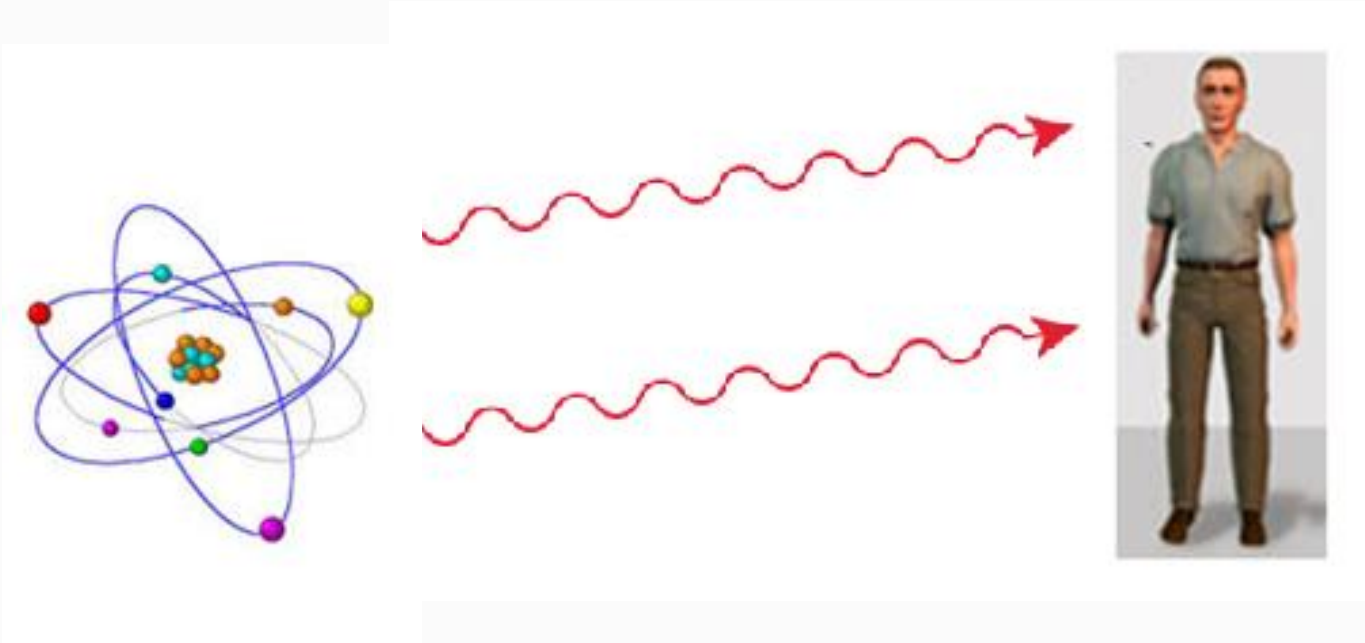
Credit: Center for Advanced Microstructures and Devices (CAMD) https://lsu.edu/camd/safety/training/radiationsafetymanual.php



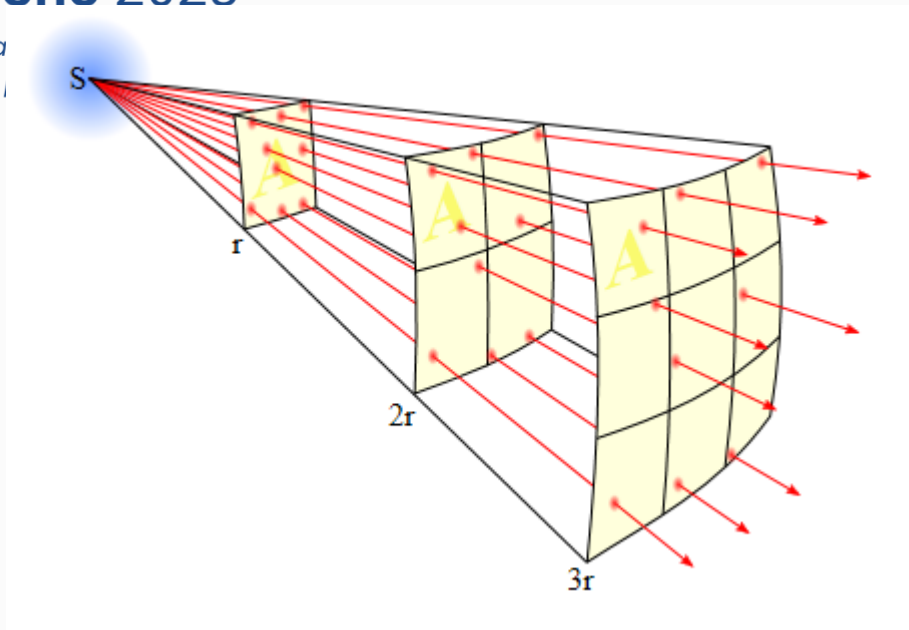
Credit: US EPA

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

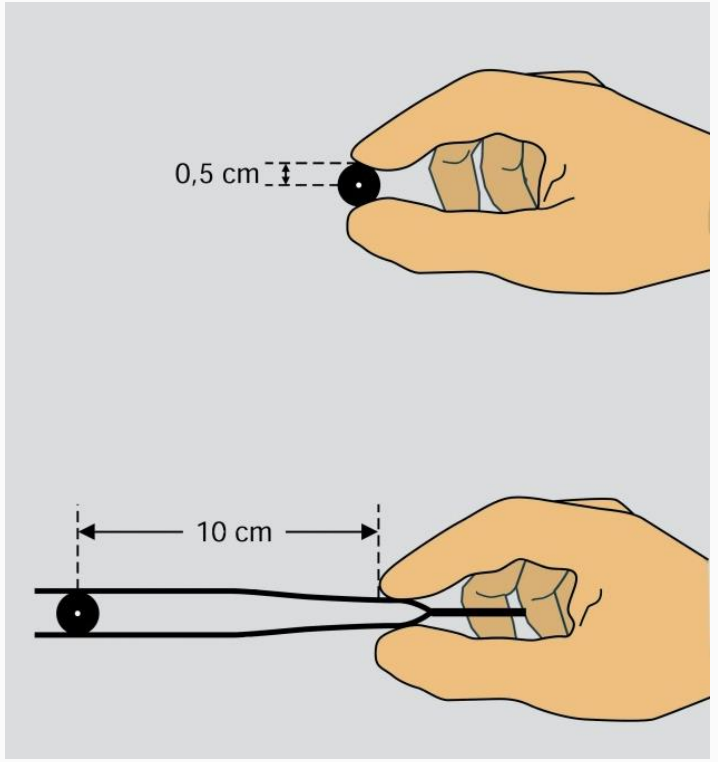
Time – Reduce



Distance – Maximize



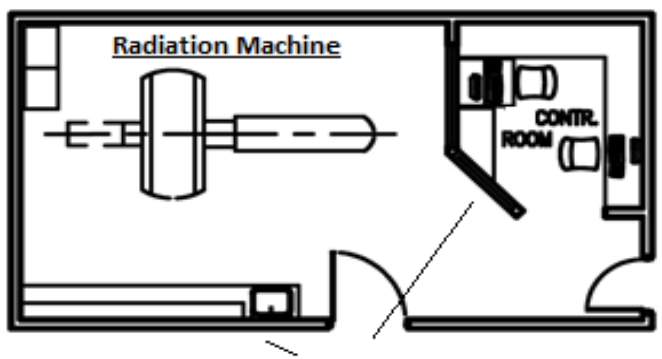
$$\text{Intensity} \propto \frac{1}{\text{distance}^2}$$



At 0.5 cm away from source
Radiation dose is 50 mSv/hr.

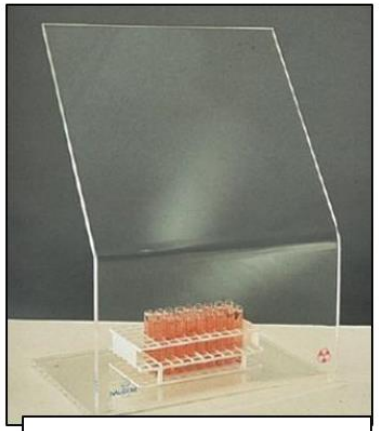
By increasing to 10 cm, the radiation dose will be
$= 50 / 20^2$
$= 50/400 = 0.125$ mSv/hr

Shielding

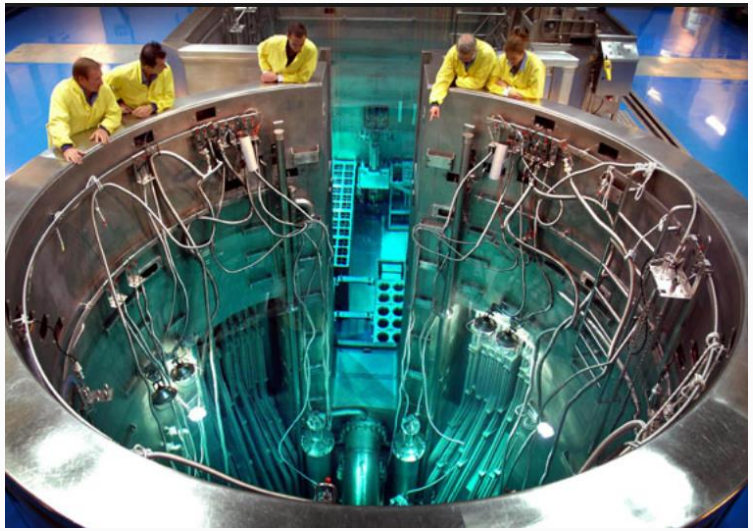


Lead Shielding in rooms

Lead Shielding



Perspex Shielding



Water as shielding in a reactor for fuel cells in ANSTO

Shielded fume hood (hot cell) for radiopharmaceuticals production

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Safe Practices working with Radiation

Hierarchy of Controls

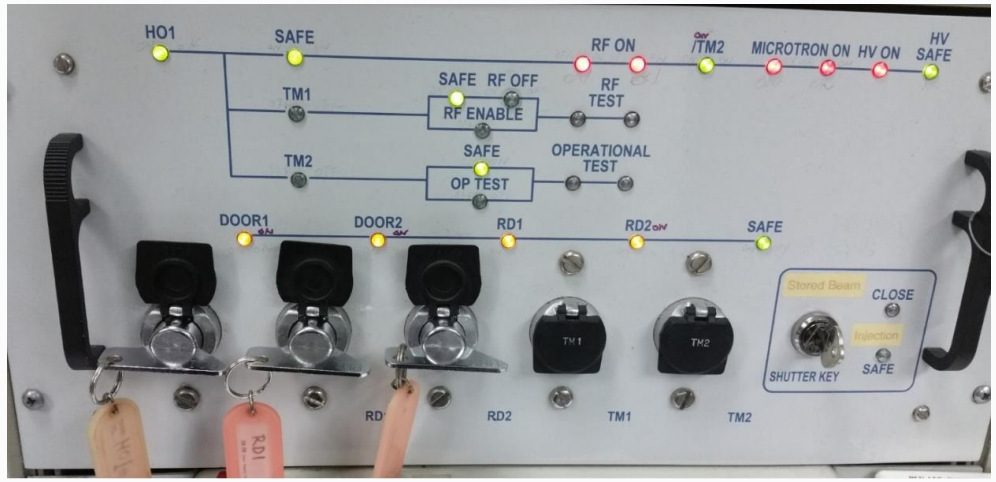
- **Elimination**
  - E.g. Use of non-radioactive gauge
- **Substitution**
  - E.g. Use smaller activity source
- **Isolation**
  - E.g Time, distance, containment, remote handling
- **Engineering Controls**
  - E.g Shielding, Interlocks
- **Administrative Control**
  - E.g Source/Activated material movement log books, regular radiation survey
- **Personal Protection Equipment**
  - E.g Lead apron

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Engineering Control

Safety Interlock System

- Interlocking system which will close and lock the room when machine is switched on
- Interlocking system of the x-ray machines when activated.



System Activation Control

- Several activation keys to be used simultaneously to switch on the machine.

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Administrative Controls

- Radiation Safety Program
- Hazard warning label, signage and lights
- Radiation Safety Training
- Radiation Licenses
- Medical surveillance (Personal Dose Monitoring)
- Radiation Area Survey Monitoring
- Safety Working Procedures

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Personal Protective Equipment (PPE)

Lead Apron for nurse/ radiographer

Lead Apron and lead glove for radiographer

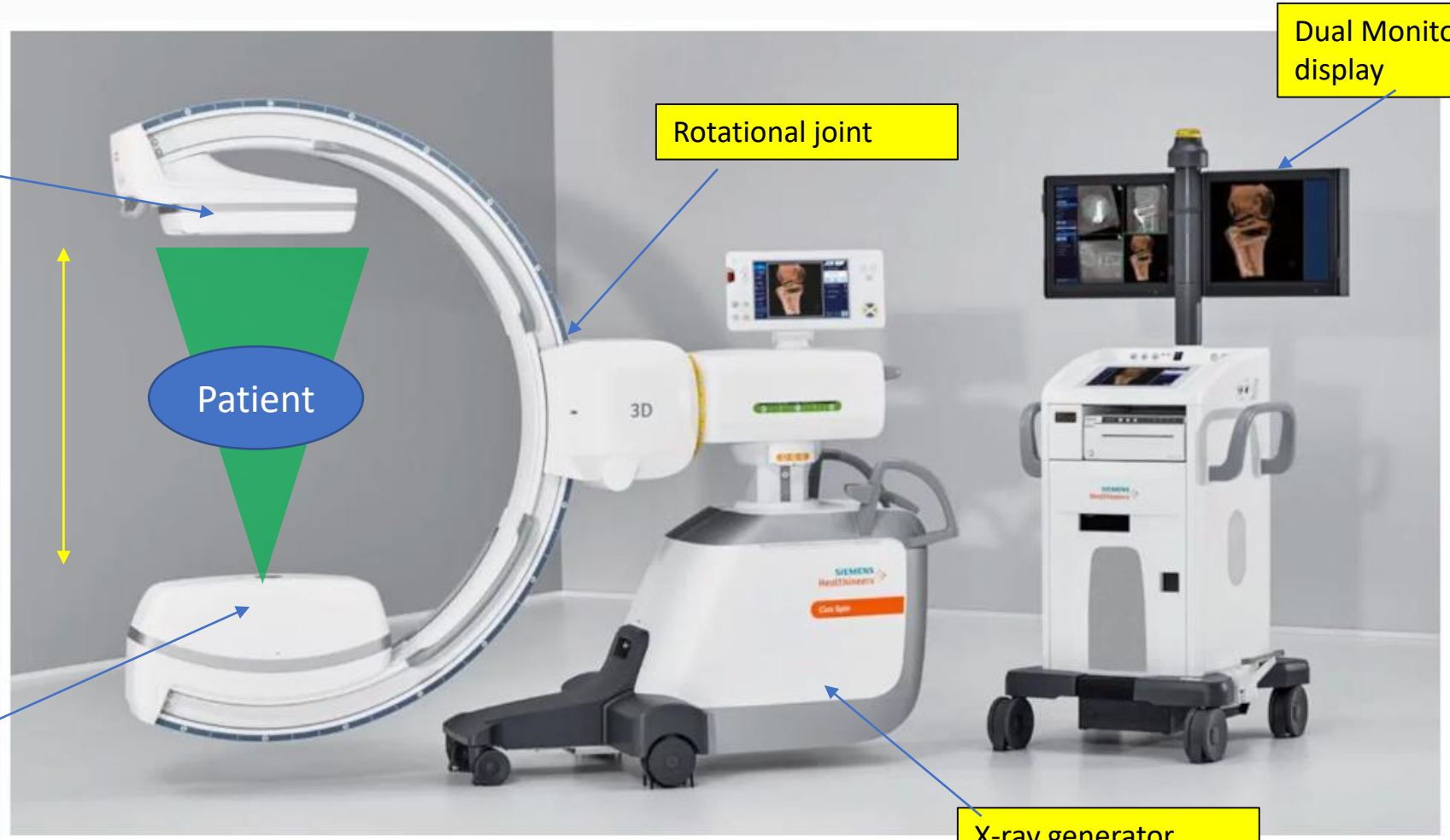
Credit: Jorvet
https://www.jorvet.com/product/x-ray-glove-lead-gloves-vinyl/

Lead Apron with collar (protect thyroid) for patient during dental-x-ray

Credit: Infab
https://www.infabcorp.com/product/adult-dental-apron-with-collar//

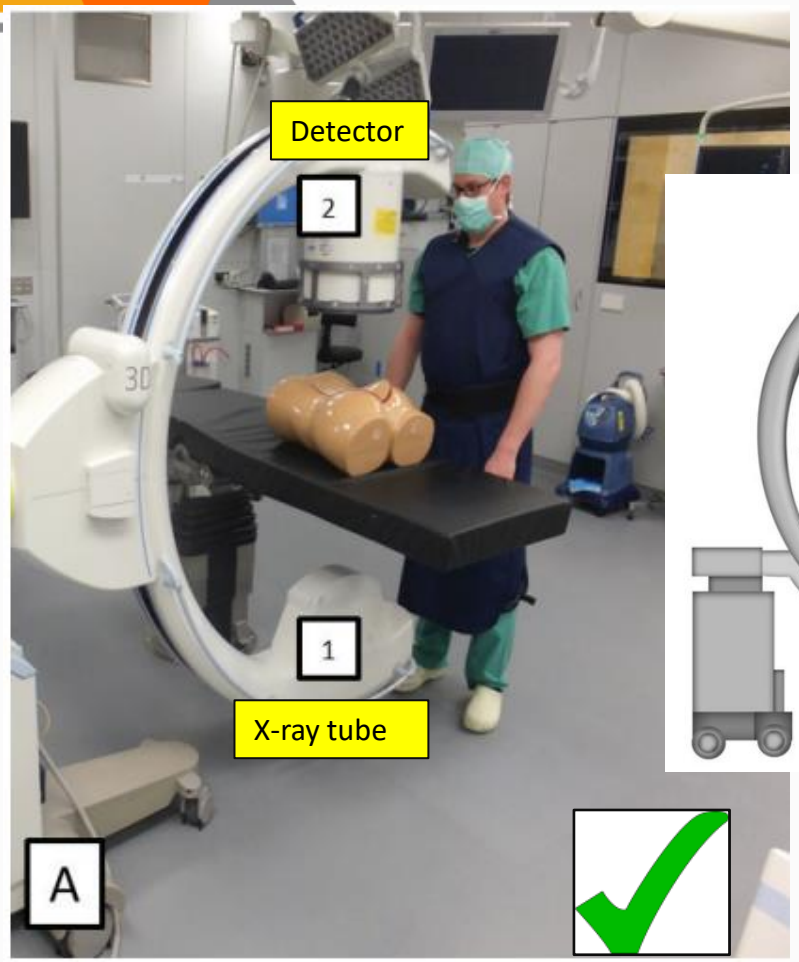
Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

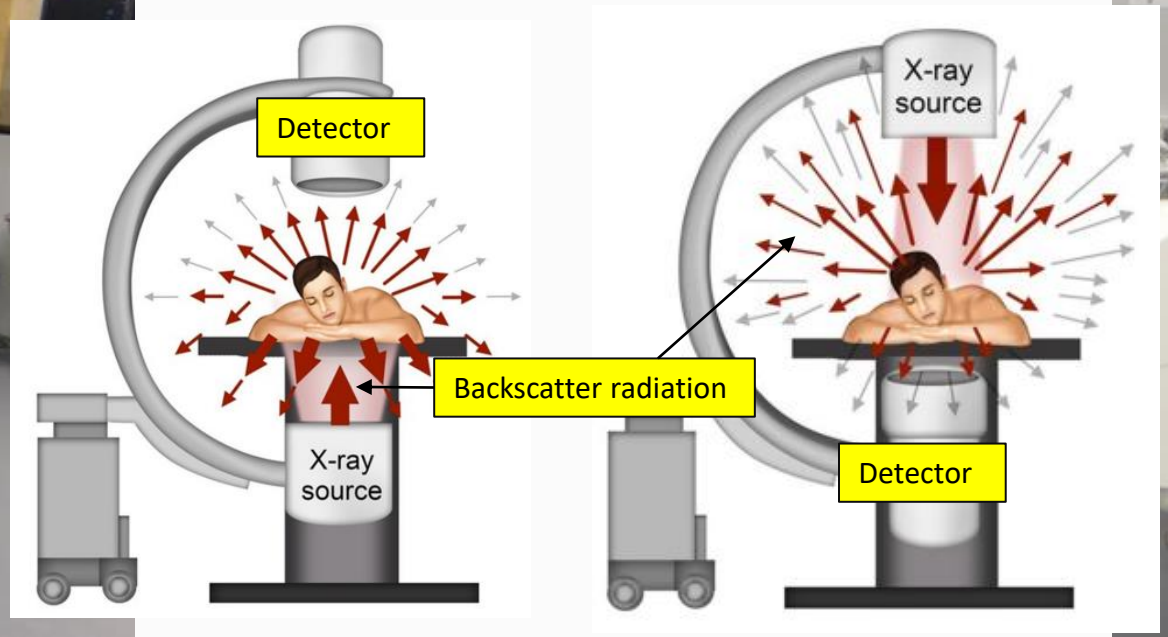
Example: C-arm fluoroscopy

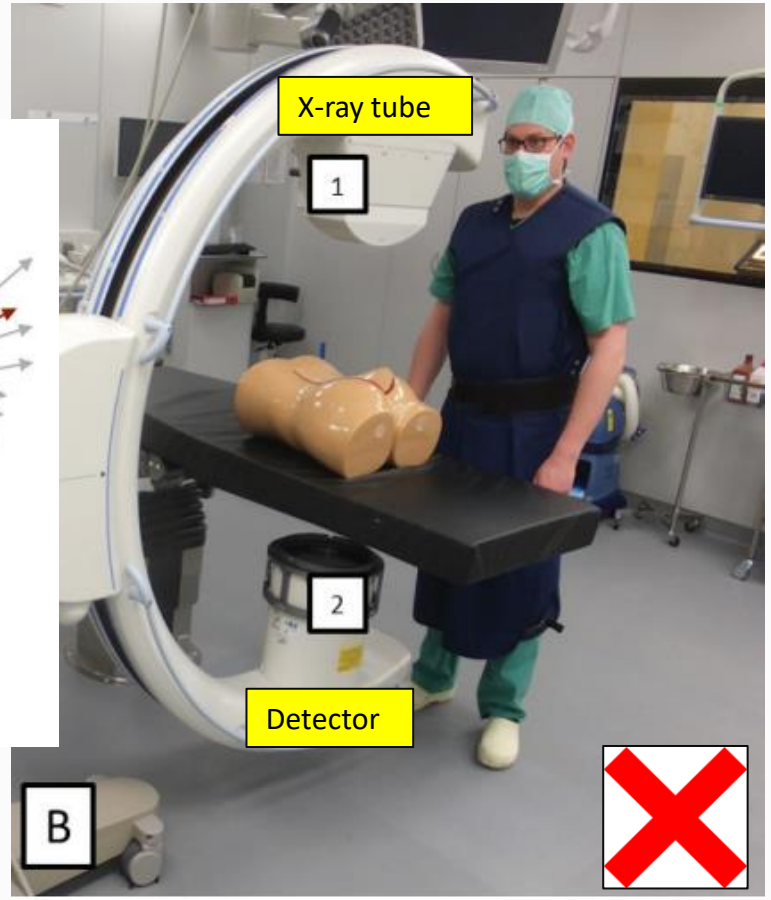


Mobile C-arm machine - Cios Spin - Siemens Healthineers

Credit: Siemens Healthineer







Picture credit: Commentary: Worldwide Knowledge and Attitude of Spine Surgeons Regarding Radiation Exposure LINK

Credit/source: Emission of radiation in the orthopaedic operation room: a comprehensive review LINK

Figure 1: The C-arm is placed in the so-called source inferior-position (A) and source-superior position (B). Whenever the radiation emitting source (position 1) is placed under the table and the detector (position 2) is placed above the table, most authors reported of reduced absorbed doses of surgeons. Therefore, the position shown in (A) is to be preferred.

PPE – Lead Shielding

Other additional lead shielding equipment in high level fluoroscopy labs:

A. Ceiling suspended
B. Table Skirt
C. Rollaway

Protection of Personnel

❖ **SHIELDING**

- Lead aprons - cut exposure by factor of 20
  - distant scatter: 0.25 mm Pb eq
  - direct involvement: 0.5 mm Pb eq
- Proper storage (hanging vs. folding)
- Thyroid collars; eye glasses; wrap around aprons
- Properly used ceiling mounted shields
- Use shielded rooms

Credit: Yale New Haven Health

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Example: NDT in industrial setting

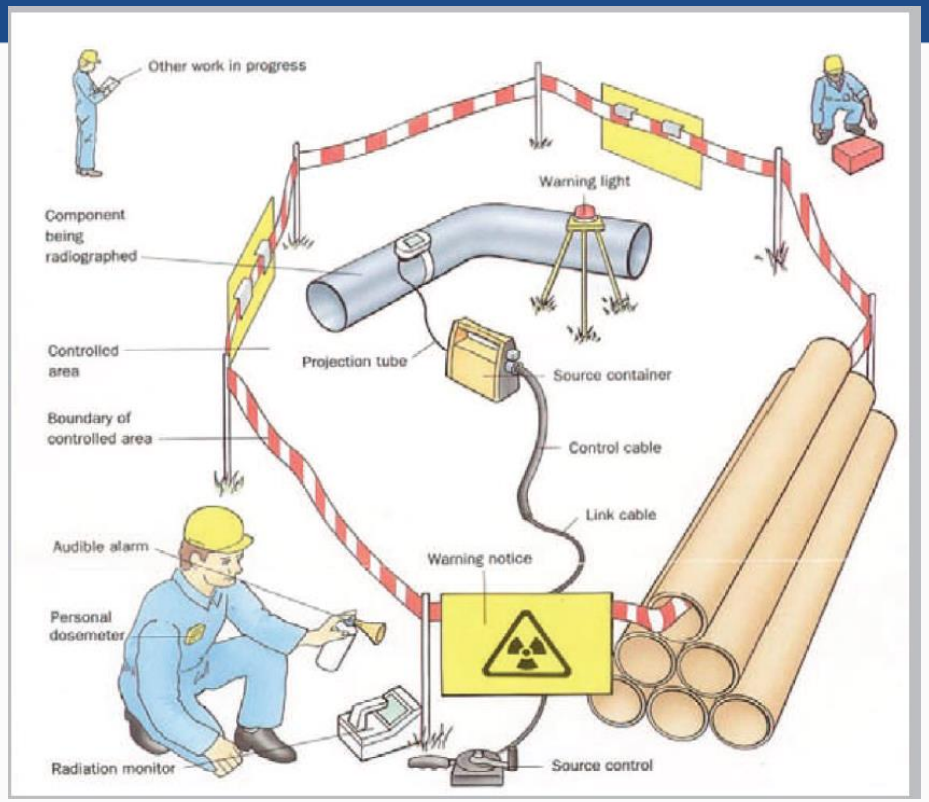
Warning notices and signals

Notices are displayed at the barriers to explain access restrictions and the meaning of warning signals.

Controlled area: Radiation

No unauthorized entry

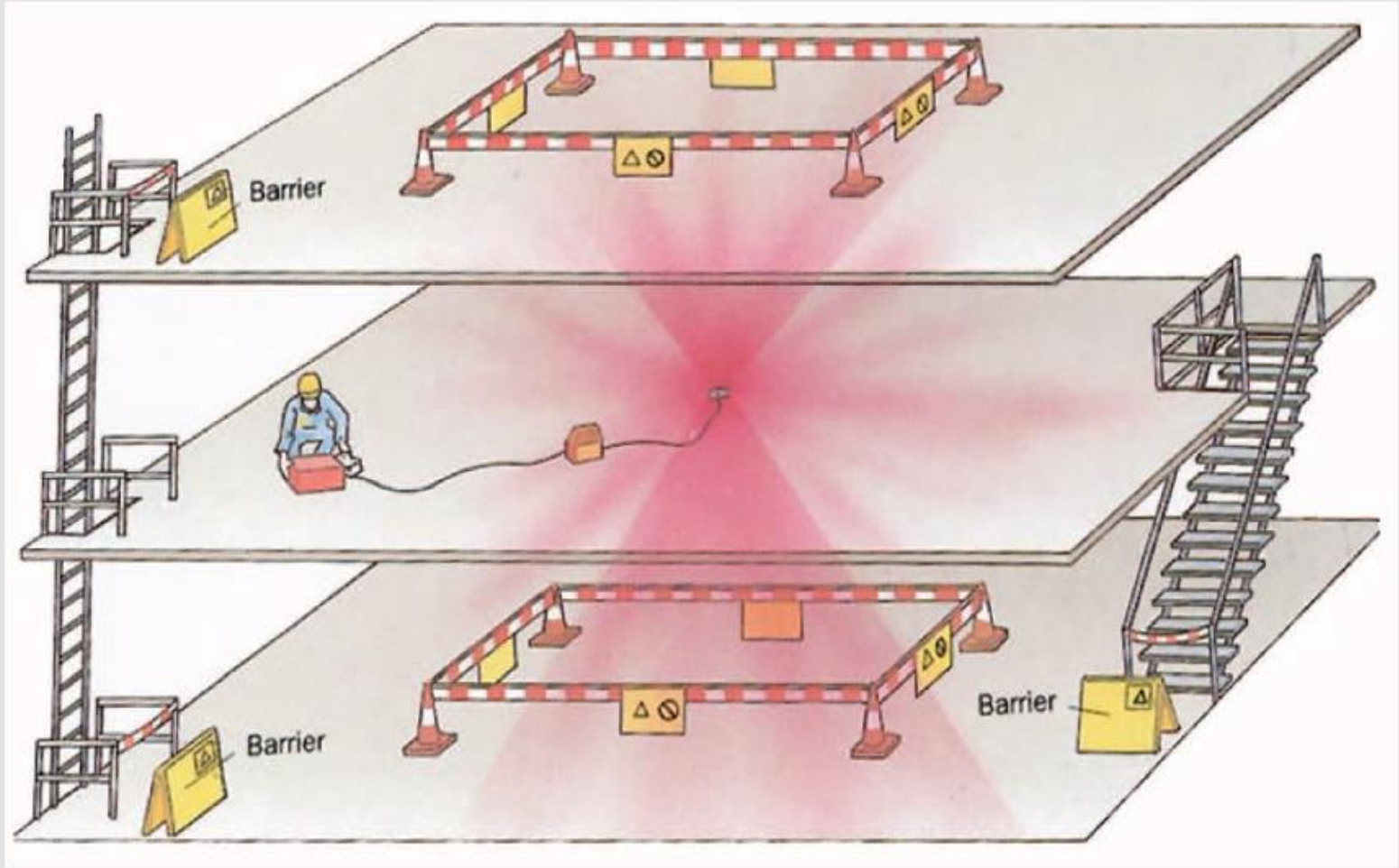
A radiographer checking that the radioactive source is safe.



Credit: IAEA – Radiography

Ergonom
Hygiene
Collaboration for S
Health in Future of

Radiography is also carried out on-site, where objects cannot be easily moved or an enclosure is not practicable. Provisions should be implemented to ensure that people are not present in the areas with a radiation hazard.



Barriers are placed at access points above and below the location of the work.

Credit: IAEA – Radiography

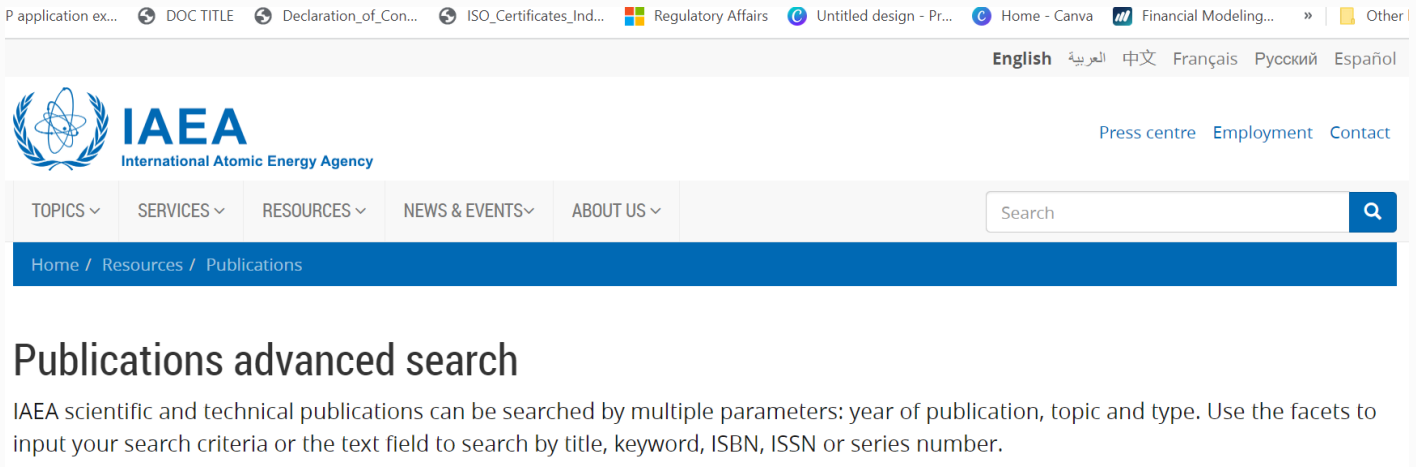
Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

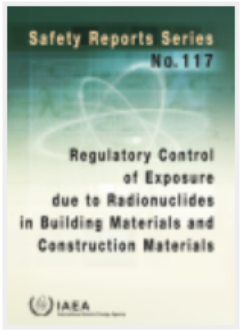
Summary

- What is Ionising Radiation?
- Sources of Ionising Radiation
- Type of Ionising Radiation
- Measuring Radiation
- Biological Effects of Radiation
- How do you “see” Radiation – Detection and Monitoring
- Radiation Safety and Protection (Time, Distance and Shielding)

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Reading Materials





Regulatory Control of Exposure Due to Radionuclides in Building Materials and Construction Materials

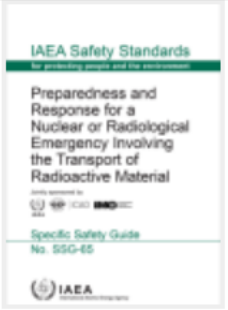
Safety Reports Series No. 117

STI/PUB/1992 ¦ 978-92-0-146522-1

Compliance Assurance for the Safe Transport of Radioactive Material

IAEA Safety Standards Series
No. SSG-78

STI/PUB/2033 ¦ 978-92-0-141922-4



Preparedness and Response for a Nuclear or Radiological Emergency Involving the Transport of Radioactive Material

Specific Safety Guide

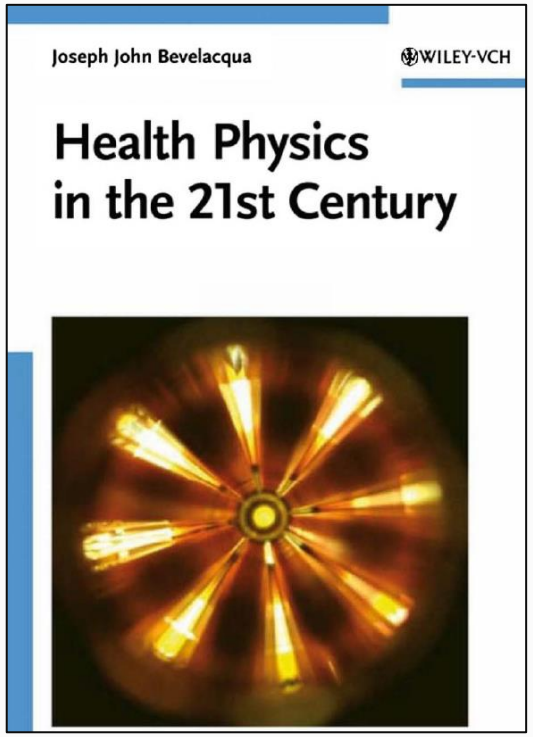
IAEA Safety Standards Series
No. SSG-65

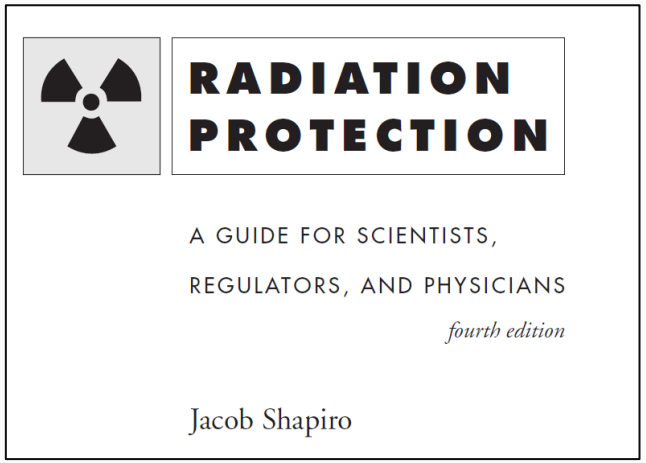
Source: https://www.iaea.org/publications

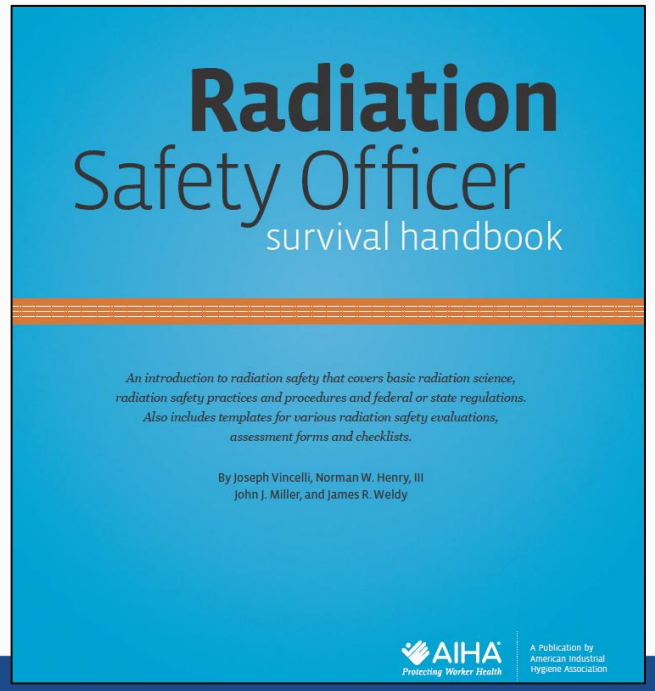
PDF is free to download

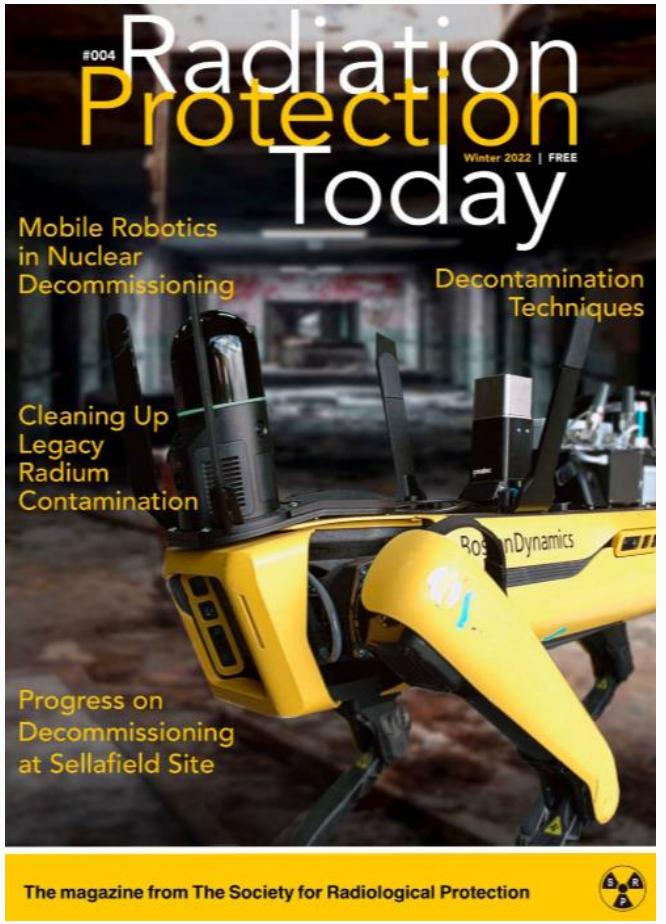
Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Reading Materials









Radiation Safety Officer = Health Physicist

Magazine from UK Society for Radiological Protection
https://srp-rpt.uk/radiation-protection-today-winter-2022-issue-4/040214800167095677 3

Ergonomics & Hygiene 2023
Collaboration for Sustainable Health in Future of Work

Any question?

Thank you!

If you want to know more details, scan the QR code of my LinkedIn.