Risk Mitigation Strategies for Radiation Incidents in Laboratories

PennState
Physical Plant

Environmental Health and Safety

Lab Safety Week
Feb. 10-13th 2025

The virtual presentations this week will be recorded, and your participation constitutes your consent.

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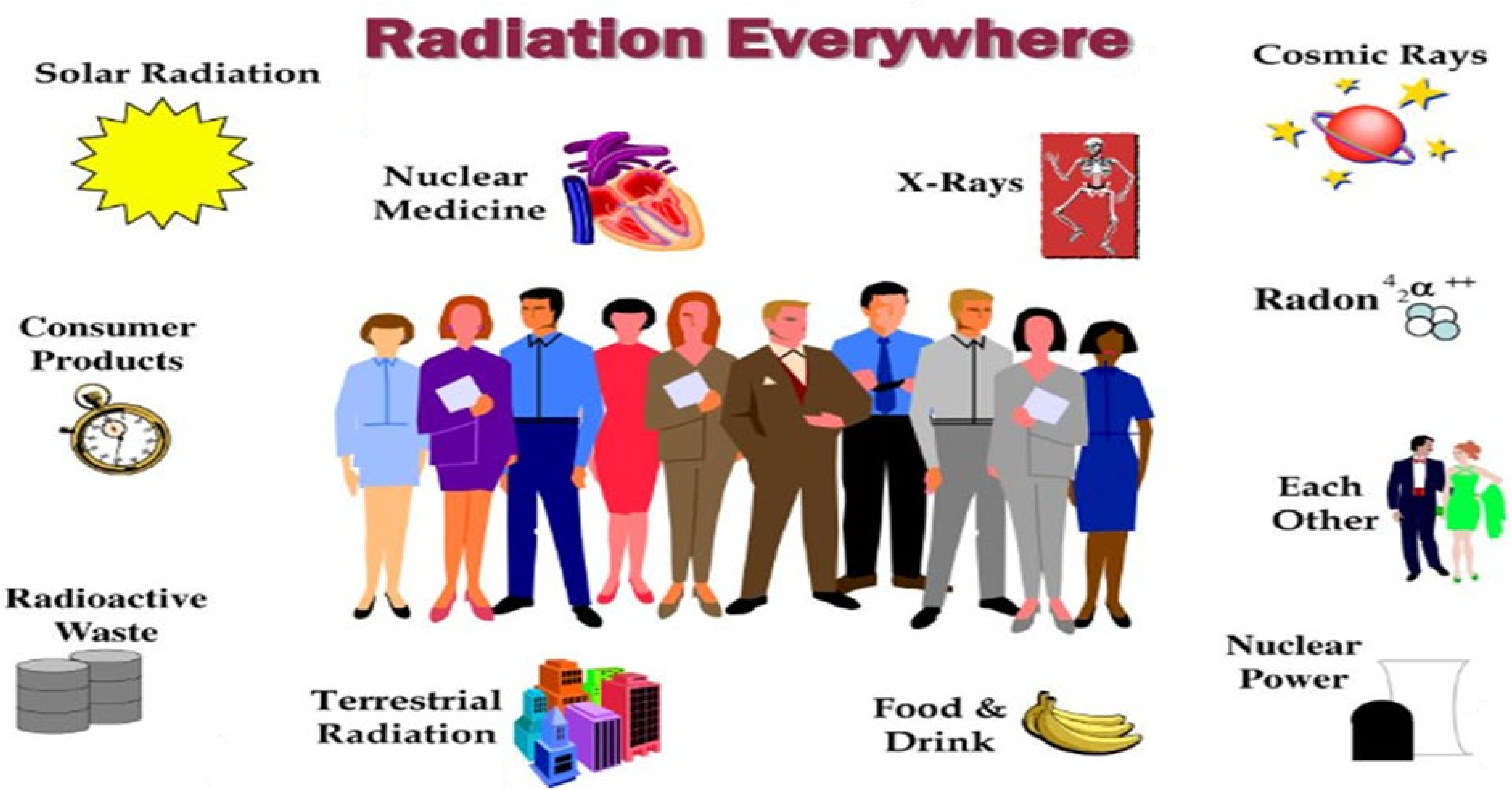
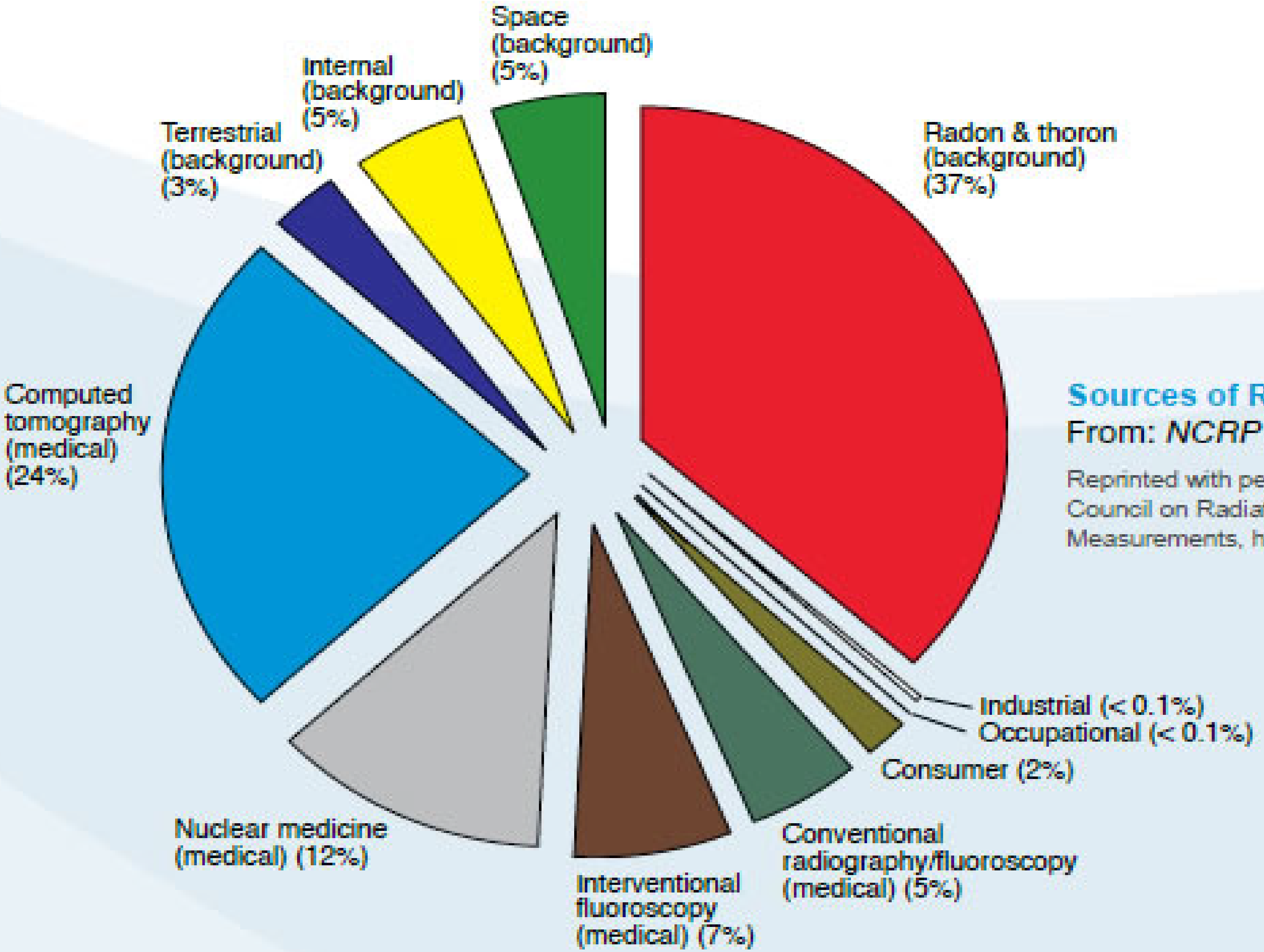
- Introduction
- Ionizing Radiation
- Radiation Hazard
- Risk Mitigation Strategies
- ALARA Principle

Introduction

Is There Radiation in This Room?


Radiation Everywhere
Solar Radiation
Cosmic Rays
Nuclear Medicine
X-Rays
Radon
Consumer Products
Each Other
Radioactive Waste
Nuclear Power
Terrestrial Radiation
Food & Drink



Sources of Radiation Exposure

From: *NCRP Report No. 160*

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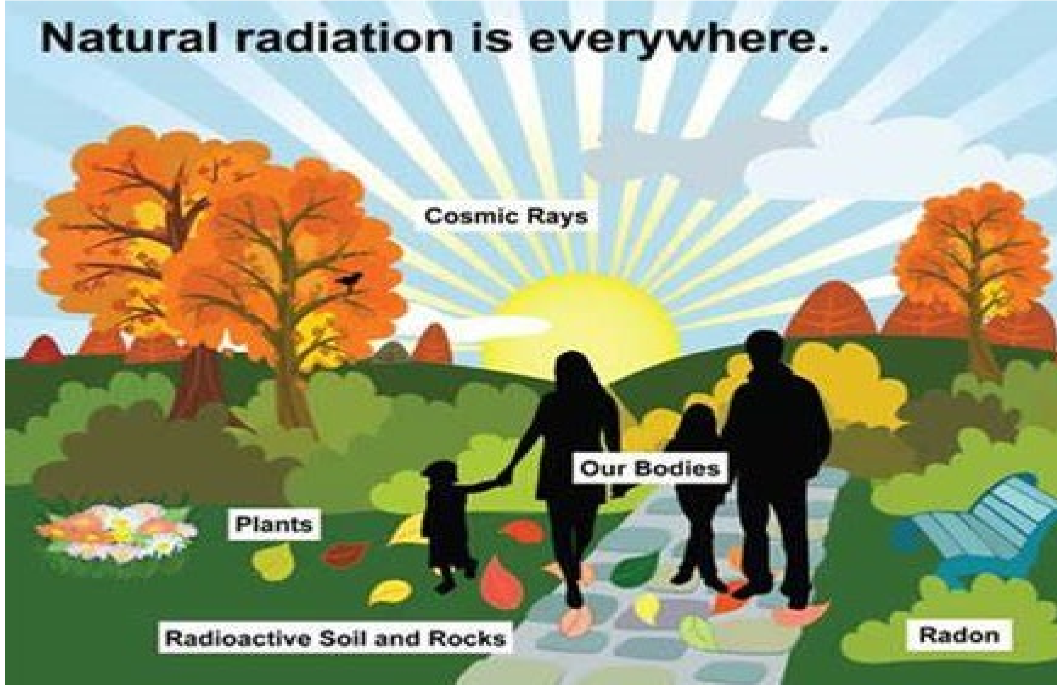
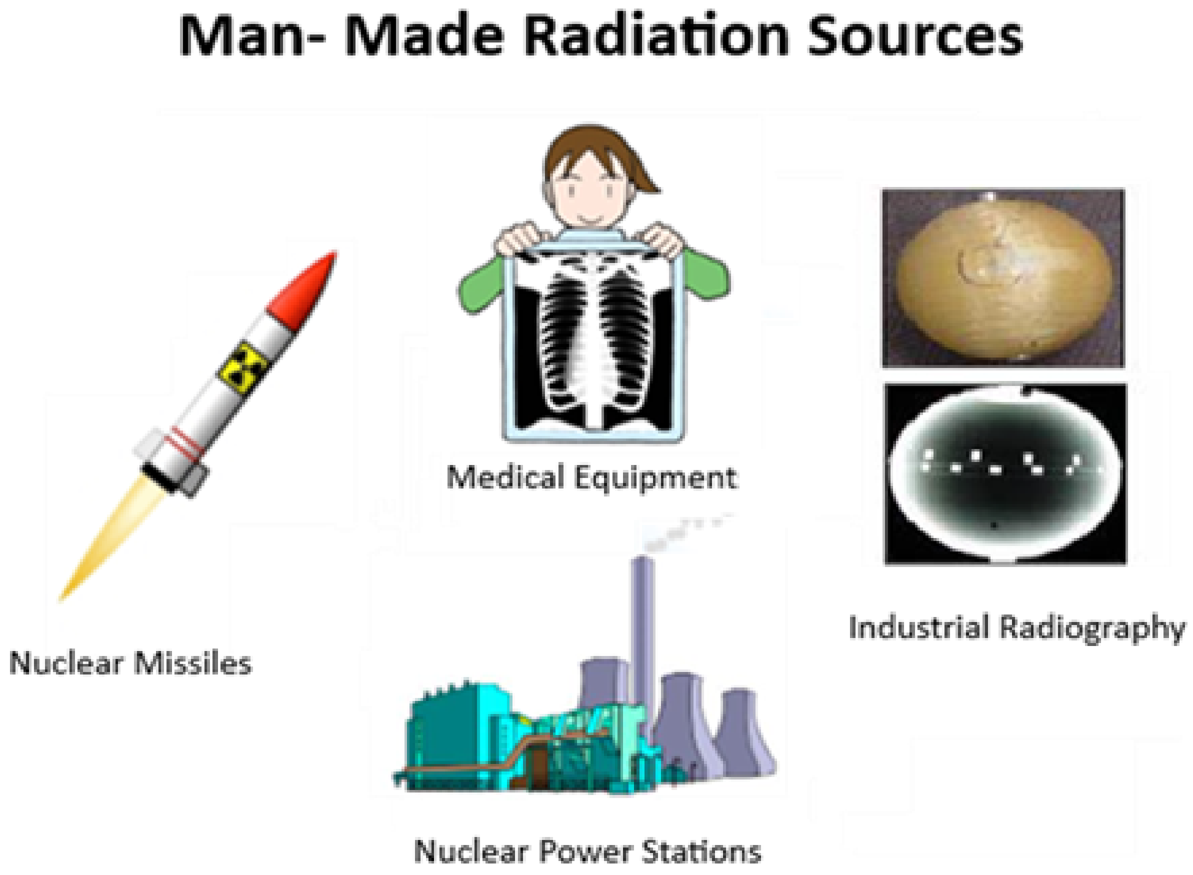
Natural Radiation Vs. Man made Radiation

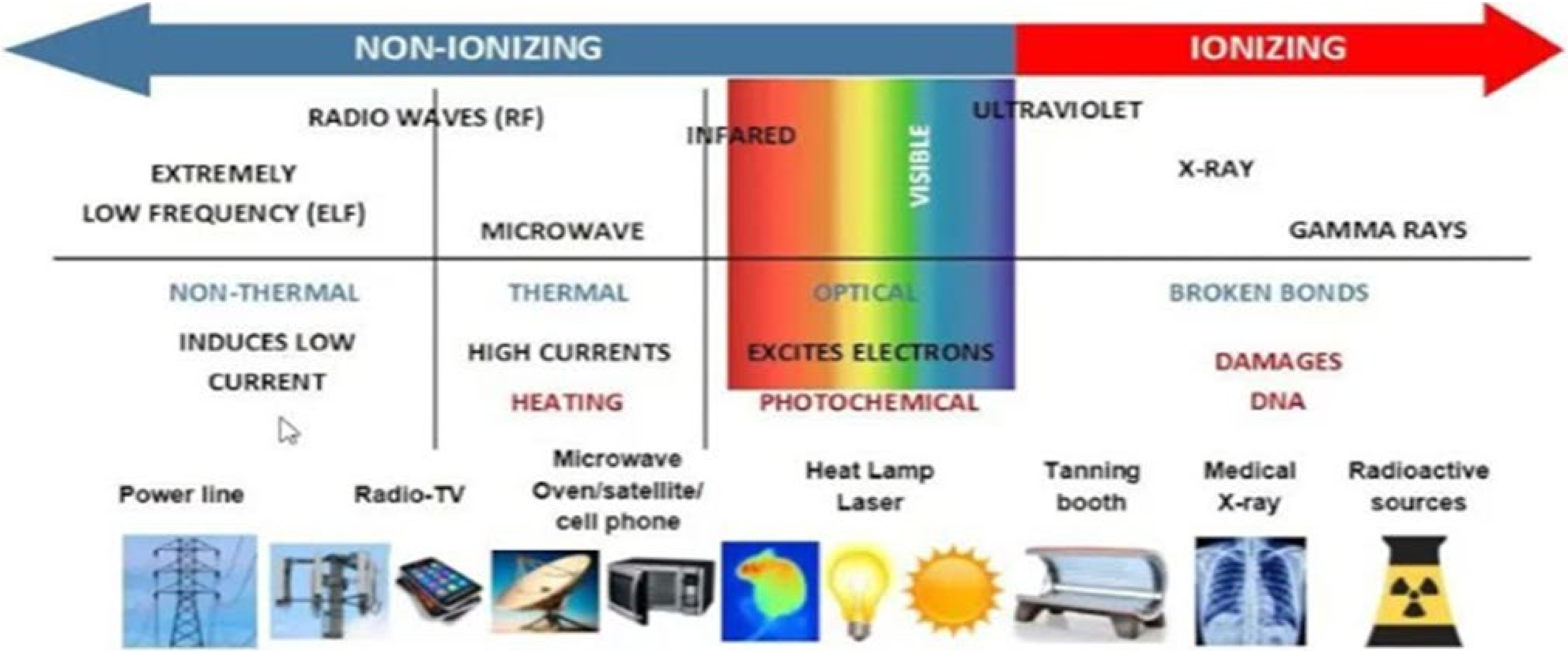




Radiation

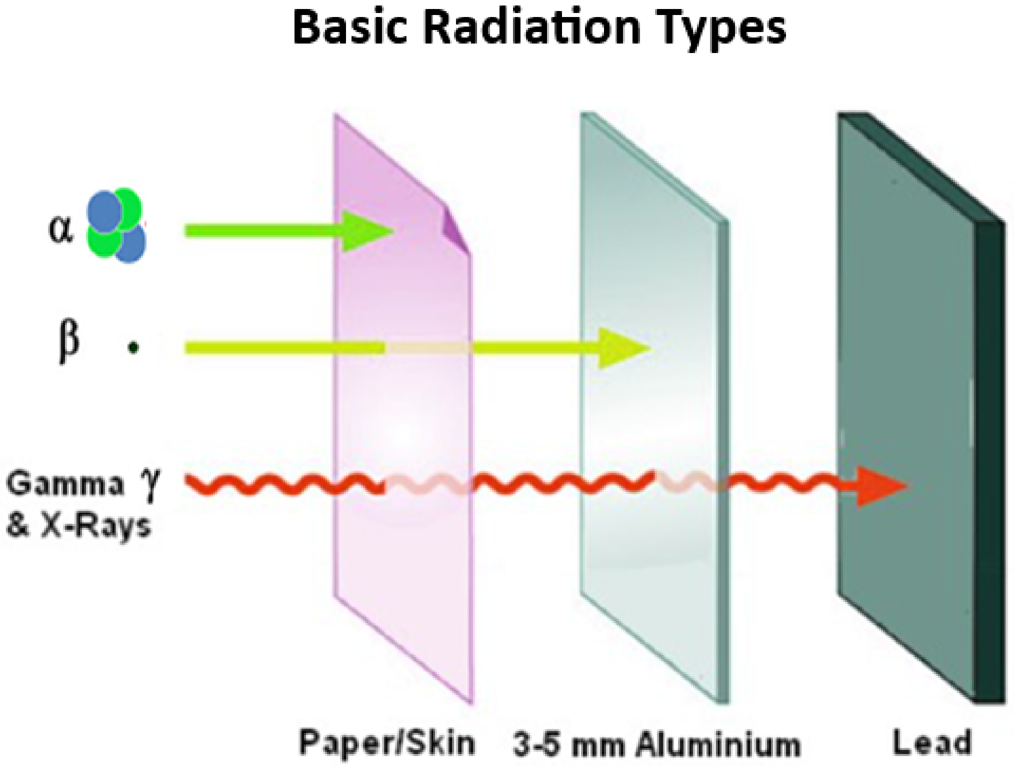
- Radiation refers to the emission of energy in the form of waves or particles.
- There are two main types of radiation:
  - Ionizing radiation
  - Non-ionizing radiation

Ionizing and Non-ionizing Radiation



Ionizing radiation

- Alpha particles
- Beta particles
- Gamma rays
- X-rays

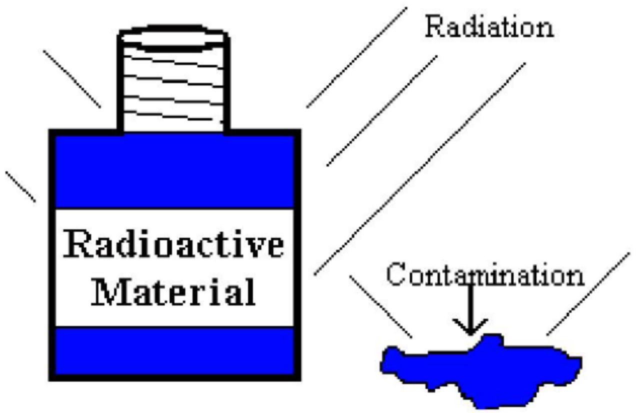


Alpha, Beta, and Gamma properties

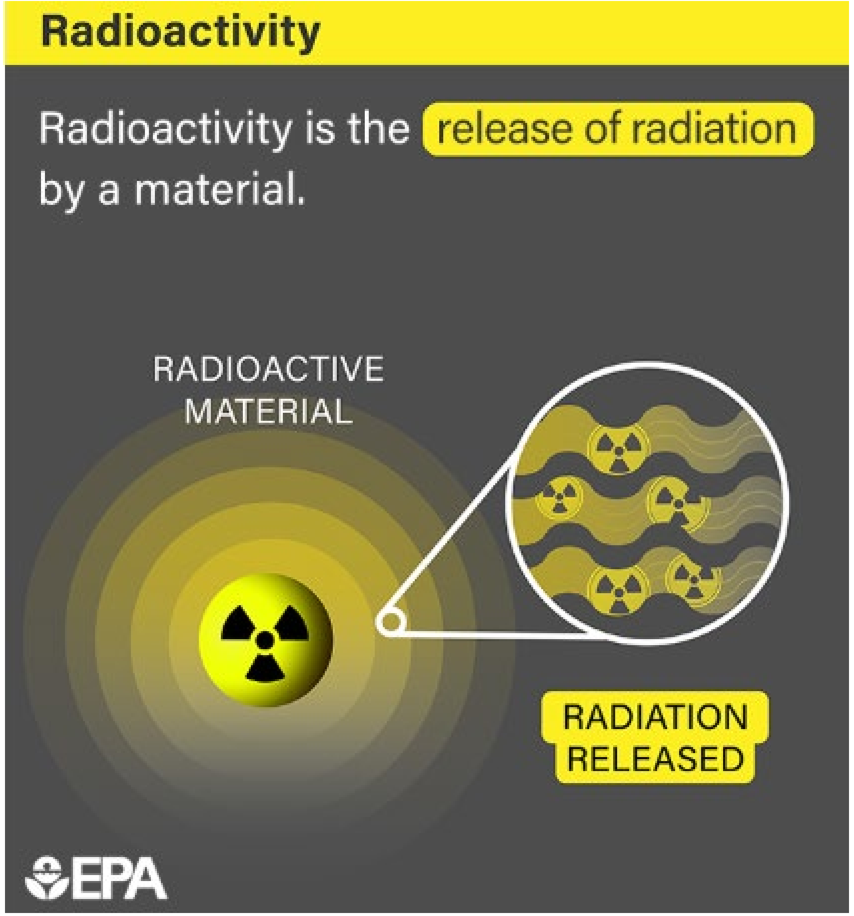
	Alpha (α)	Beta (β)	Gamma (γ)
Nature	It's a nucleus of helium ^4_2He. Two protons and two neutrons	It's an electron e^-	It's an electromagnetic wave
Charge	+2	-1	0
Mass	Relatively large	Very small	No mass
Speed	Slow	Fast	Speed of light
Ionizing effect	Strong	Weak	Very weak

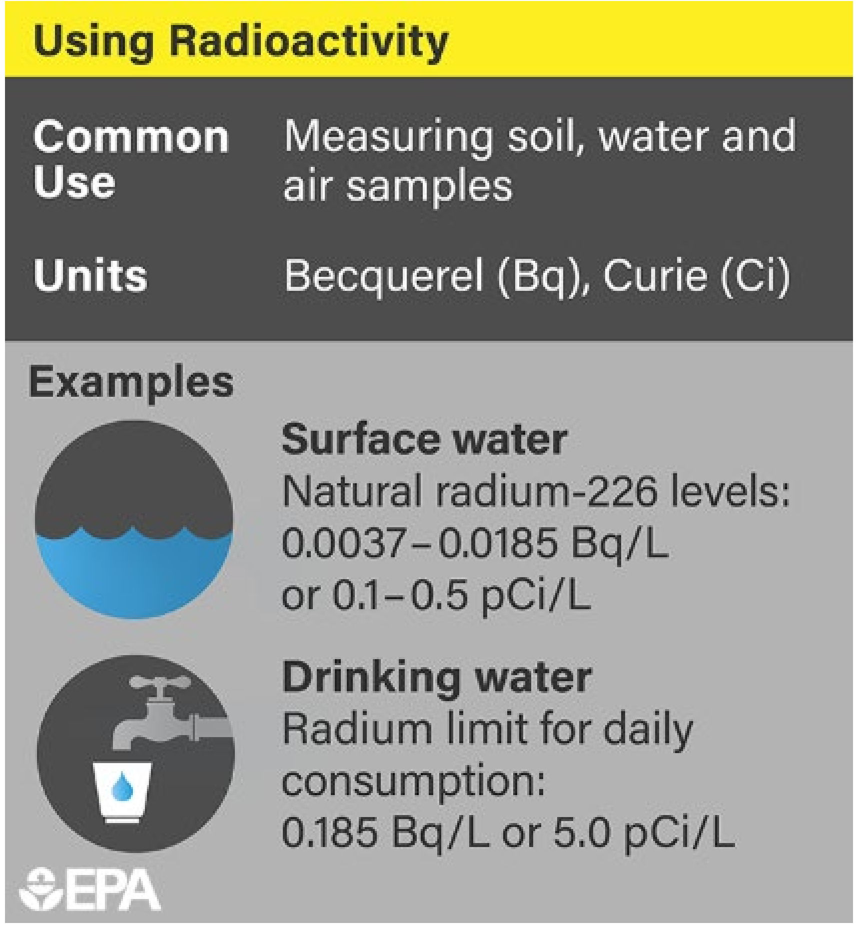
Radioactive Materials Vs. Radioactive Contamination

	Radioactive Materials	Radioactive Contamination
Definition	Substances that contain unstable atoms emitting radiation.	Presence of radioactive material in unintended places.
Location	Stored or used in controlled settings.	Found on surfaces, clothing, or equipment where it shouldn't be.
Risk	Risk is managed through controlled use and storage.	Risk arises from the uncontrolled spread of radioactive materials.
Example	Medical isotopes	Radioactive spill

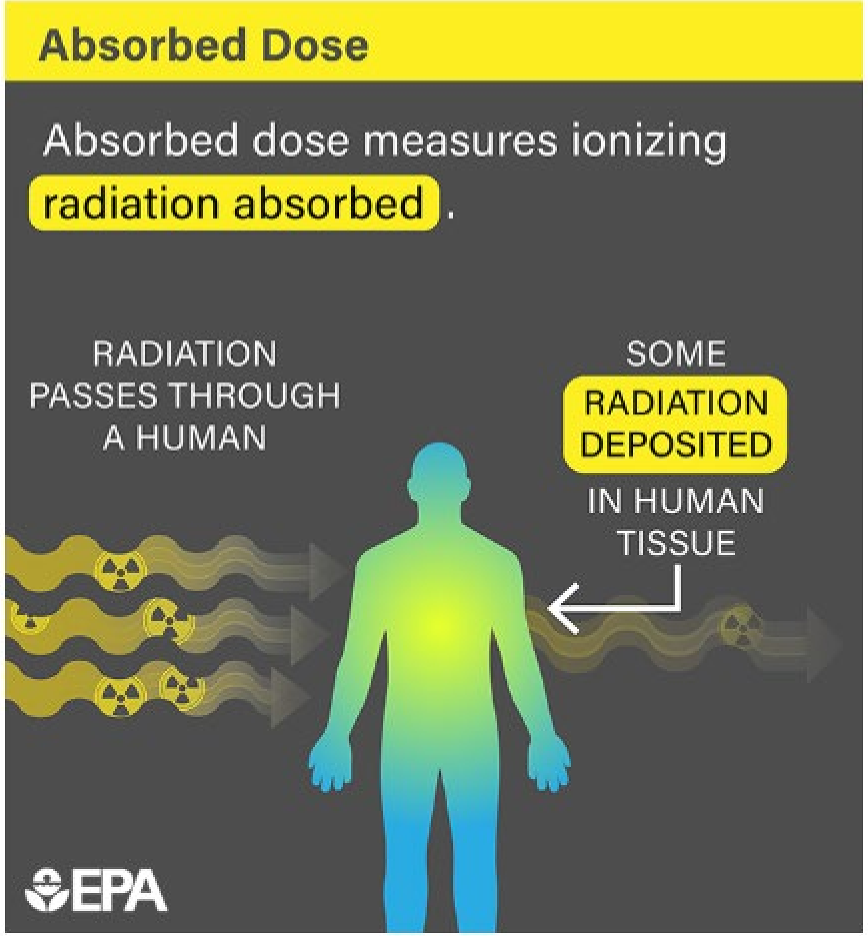


Radiation Units





Absorbed Dose



Using Absorbed Dose

Common Use	Measuring dose from medical equipment
Units	Gray (Gy), Rad (rad)

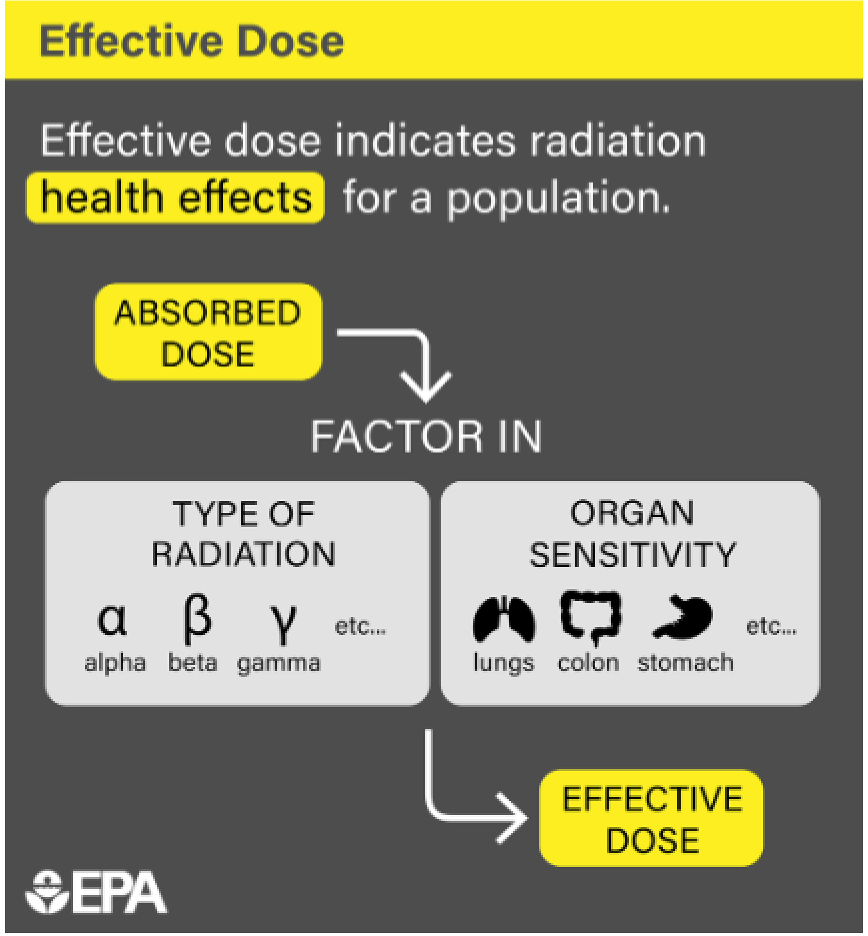
Examples

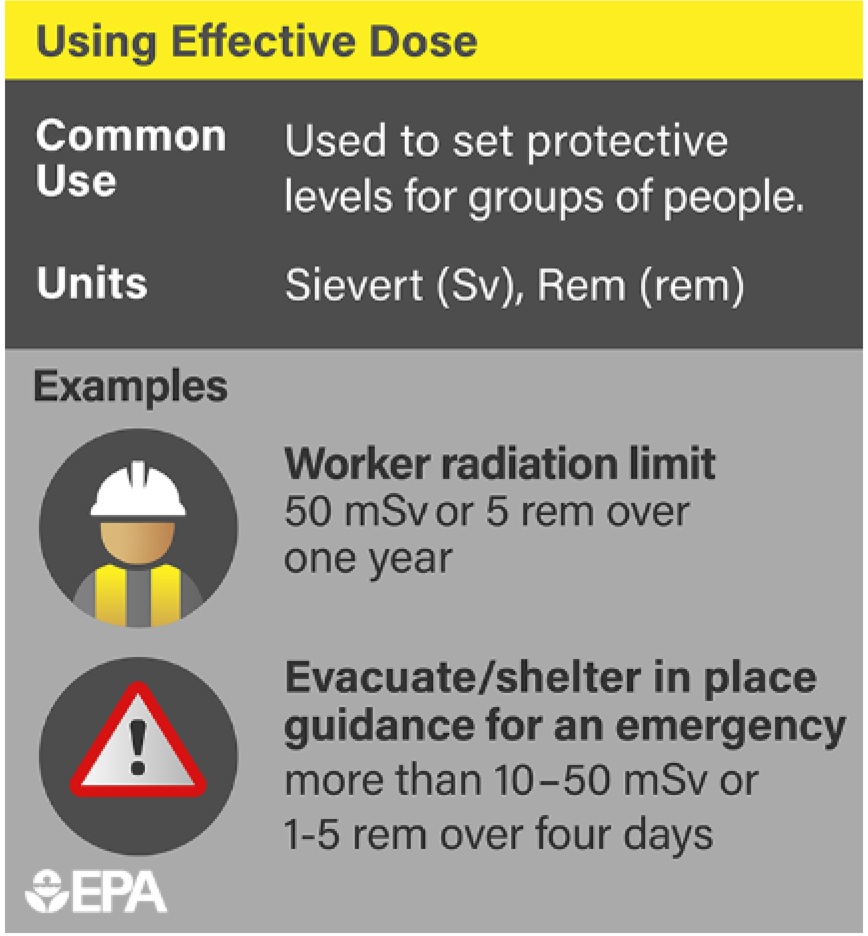
Dose to the lens of eyes from a brain CT scan
≈60 mGy or 6 rad

Dose to the thyroid from a chest CT scan
≈10 mGy or 1 rad

EPA

Effective Dose





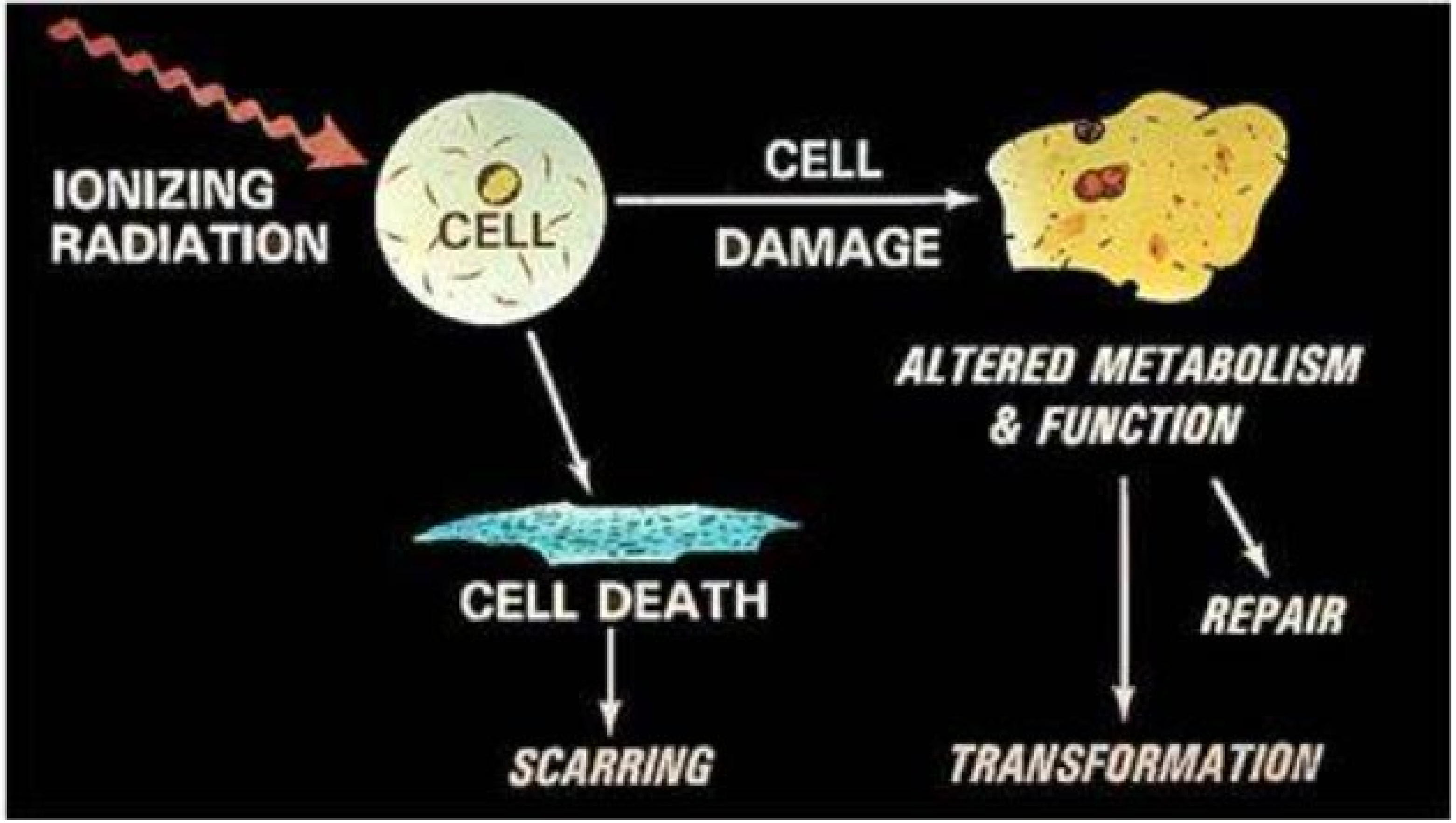
Radiation Hazard

- Low-level radiation exposure doesn't result in immediate health issues. However, over long periods of exposure, the risk of developing cancer may increase "Chronic dose"

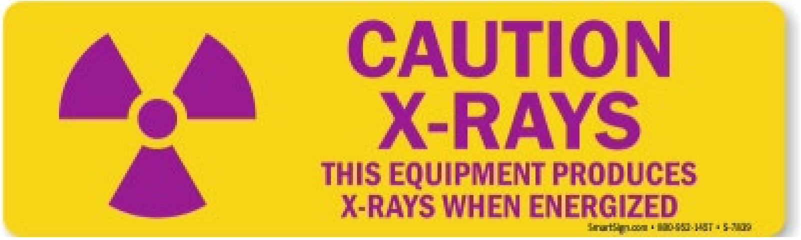
- High-level radiation exposure received in a short period of time, typically within minutes or hours, is known as an Acute dose.

- The effects of a large Acute radiation exposure can include:
  - Nausea and vomiting
  - Hair loss
  - Skin burns
  - Fever

Radiation Hazard



Radiation Hazard for Fetus



- At low doses, such as those used for common diagnostic X-rays, the risks to the fetus are generally considered minimal.
    - A single chest X-ray generally delivers about **0.1 millisievert (mSv)**, which is equivalent to about **0.01 rem**.
    - A dental X-ray (bitewing) delivers approximately **0.005 mSv**, or **0.0005 rem.**
- High doses of radiation are typically associated with situations such as therapeutic radiation treatments or accidents involving large amounts of radiation. The risks of high-dose radiation exposure, especially during pregnancy, can be significant.
    - Increased risk of childhood cancer
    - Birth defects : Radiation exposure, especially in the first trimester (when organs are forming), can cause structural defects such as heart defects.
    - Developmental disorders: Exposure to radiation can interfere with normal brain development. This can result in intellectual disabilities, developmental delays, and learning problems.

Radiation limits

NRC Limits

NRC Occupational Dose Limits

Whole Body (TEDE)	5,000 mrem/yr
Any Organ (TODE)	50,000 mrem/yr
Skin (SDE)	50,000 mrem/yr
Extremity (SDE)	50,000 mrem/yr
Lens of Eye (LDE)	15,000 mrem/yr
Embryo/Fetus of DPW	500 mrem/yr
Member of the Public	100 mrem/yr

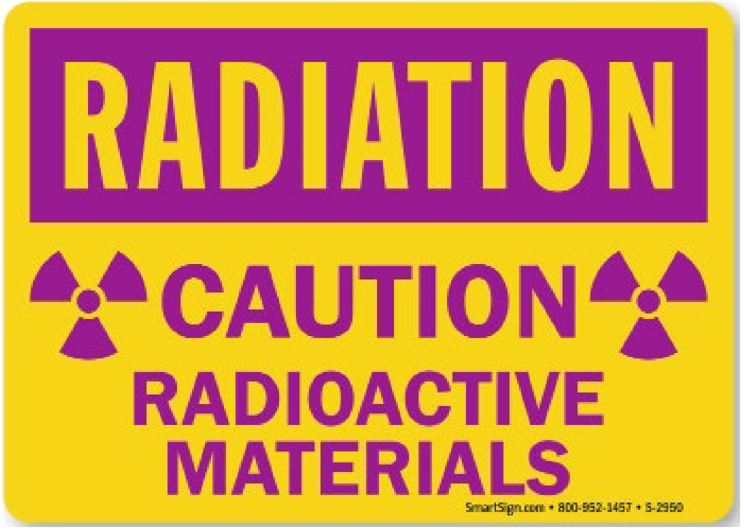
Note: 1,000 mrem = 1 rem

Fact

- We can't directly detect ionizing radiation because they are invisible to our senses. Unlike things like smoke or heat, radiation doesn't give off smells, colors, or tastes, making it difficult to notice without specialized equipment. This lack of sensory signals is one reason why radiation can be so hazardous if we aren't aware of its presence.

Radiation Laboratories

Radiation signs



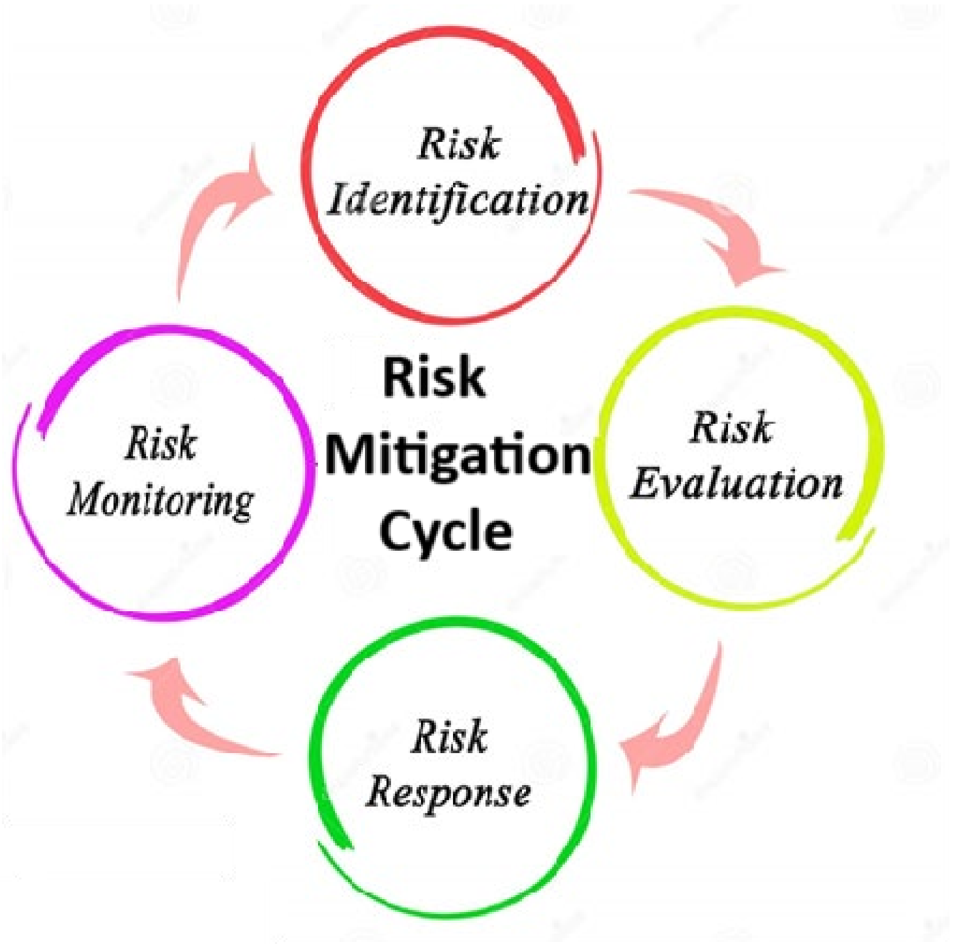
Dosimeters

- Dosimeters are devices used to measure **radiation exposure**, typically in environments where individuals might be exposed to ionizing radiation.

  - Thermoluminescent Dosimeter (TLD)
  - Optically Stimulated Luminescence (OSL)
  - Ion Chamber
  - Pocket Dosimeter
  - Personal Electronic Dosimeter (PED)

Portable Radiation Survey Meters

Risk Mitigation Strategies



Risk Mitigation Strategies

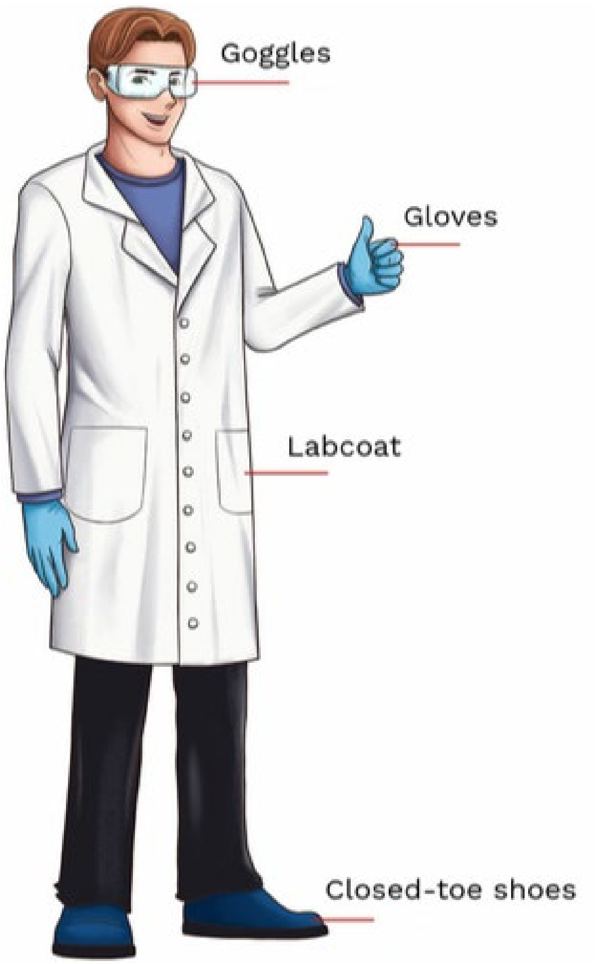
- **Personal Protective Equipment (PPE)**

    - When working in areas with potential radiation exposure, always use your PPE, such as a lab coat, gloves, and lab glasses.

    - If you are assigned a radiation dosimeter, wear it when working in the radiation lab, as it will help monitor your exposure dose level over time.

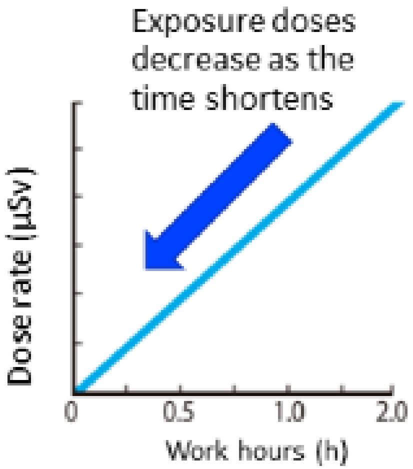
Risk Mitigation Strategies

- **ALARA Principle**
  - ALARA stands for "As Low As Reasonably Achievable" and is a key safety principle used to minimize radiation exposure to individuals.
  - *Three Protection Principles of Reduction of External Exposure*
    - Time
    - Distance
    - Shielding



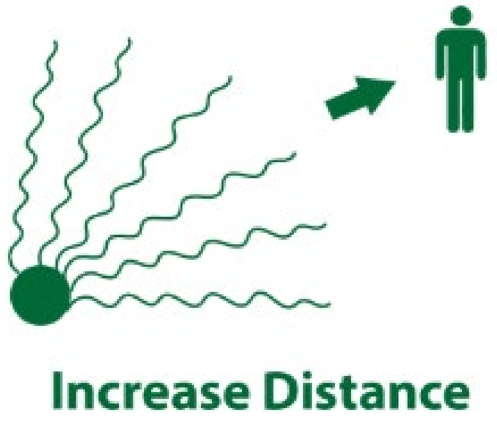
Time

- Minimizing the exposure time reduces a worker's dose from the radiation source.
- The longer you stay near radiation, the higher your exposure will be.



Distance

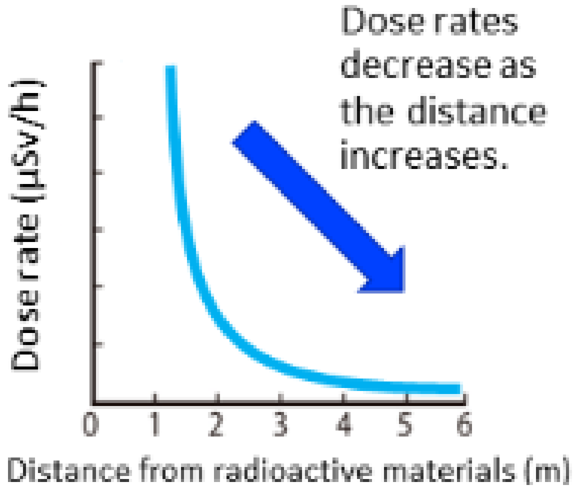
- Increase the distance between yourself and the radiation source. Radiation exposure decreases with the square of the distance from the source
  - Inverse square law



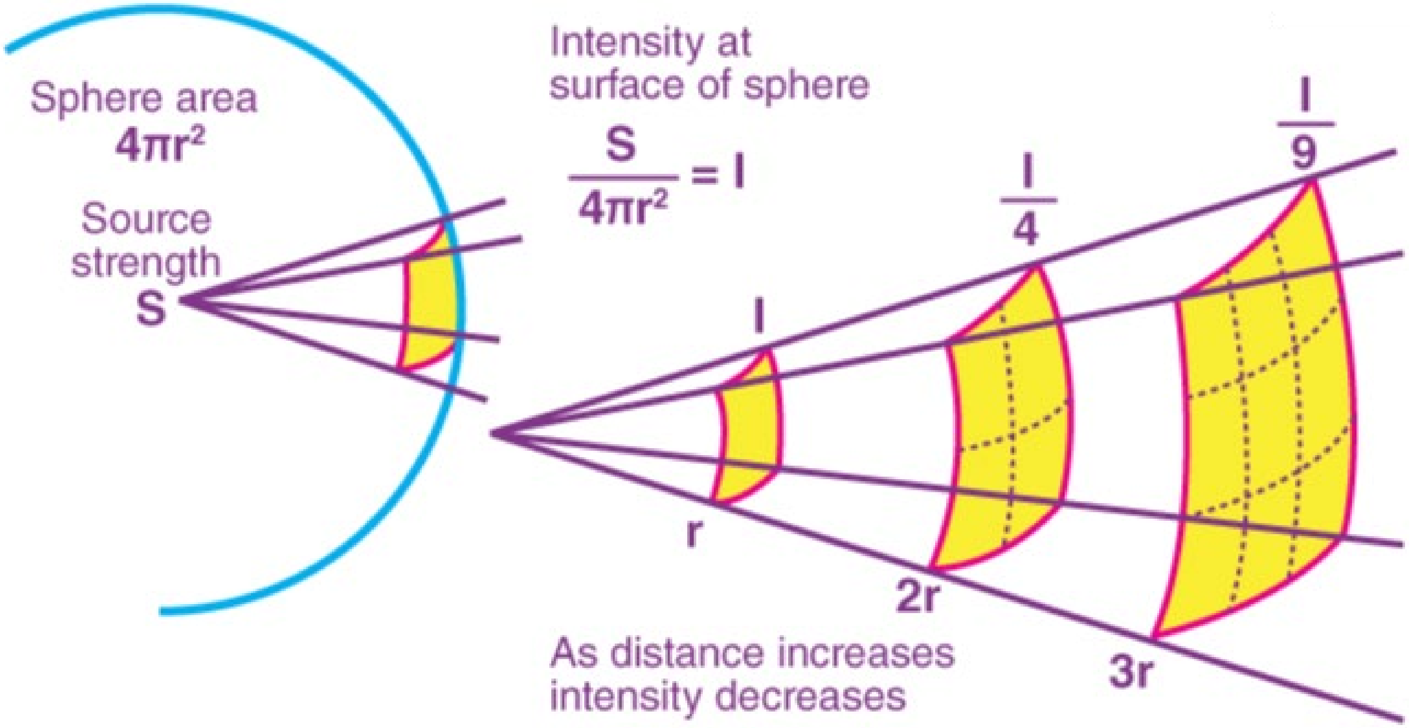
The Inverse Square Law

$$\frac{I_1}{(I_2)} = \frac{(d_2)^2}{(d_1)^2}$$

I_1 is the initial intensity of radiation, d_1 is the initial distance, and d_2 is the final distance, and I_2 is the final intensity.



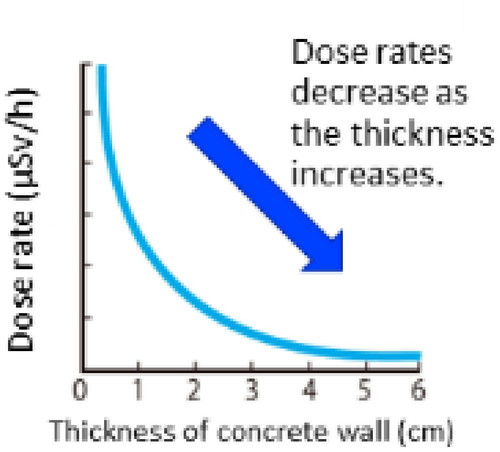
Distance



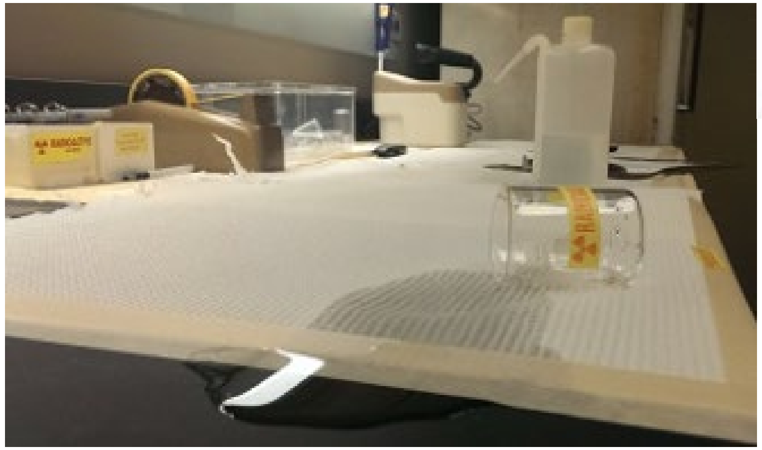
Sphere area
4πr²
Source
strength
S
Intensity at
surface of sphere
S / 4πr² = I
I
I/4
I/9
r
2r
3r
As distance increases
intensity decreases

Shielding

- Use appropriate shielding materials to block or reduce radiation exposure. For example, lead shields are commonly used to protect against X-rays and gamma radiation, while materials like plastic or glass can protect against beta radiation.



Radiation spill Response



Radiation incident in Laboratory

- Radiation spill
  - Small Radiation spill
  - Large Radiation spill

SWIM Concept “ Stop Warn Isolate Minimize”

Example 1

- **In the case of small spill:**
  - The radiation worker can handle the spill by following the correct procedure:
    - Wear the appropriate PPE.
    - Stop the spill and warn others.
    - Clean up the spill.
    - Survey the area.
    - Document what happened and contact your supervisor and the RSO to report the incident.

- *Note:* In the case of a life-threatening situation, call 911 first.

Example 2

- **In the case of Large spill:**
  - The radiation worker will need external help.
  - In the case of a life-threatening situation, call 911 first.
  - ***The steps you should follow:***
    - Wear your PPE
    - Stop the spill and warn others in your lab.
    - Isolate the spill place and go to a safe place.
    - Call the EHS emergency line for support

- **Radiation Safety Emergency Phone: (814) 777-0215**

- Lab 8: Spills and Decontamination

References

- Radiation Protection | PPT
- Radiation Terms and Units | US EPA
- Knoll, Glenn F. *Radiation Detection and Measurement*. 4th ed. Hoboken, NJ: Wiley, 2010.
- Chapter 3 - Radiation Protection Standards and Guides, NRC
  - SART, Chapter 3 - Radiation Protection Standards and Guides (Site Access Refresher H101).

Questions

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