SAND2011-0509P

Basic Health Physics

Introduction to WMD Science

SAND No.
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

International
BIOLOGICAL THREAT REDUCTION

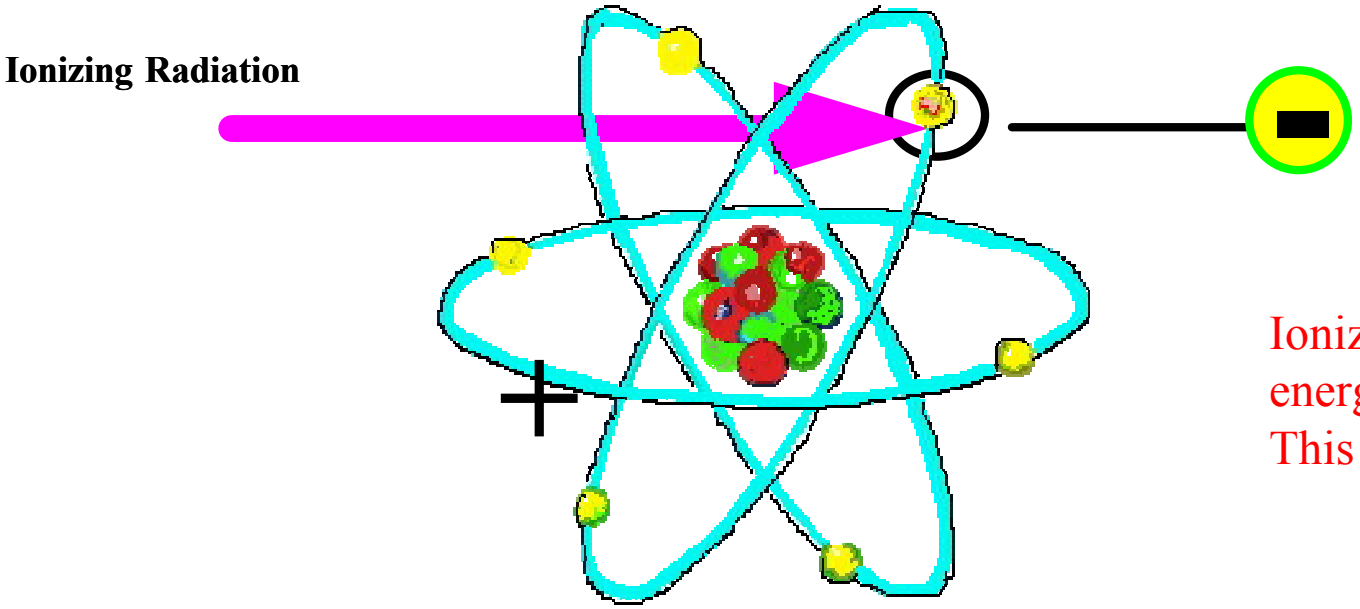
Objectives

- Explain the terms dose, dose rate, and activity.
- Explain how dose rate, dose, and activity are related.
- Describe the difference between radiation and contamination.
- Explain how to minimize your total dose using the concepts of time, distance, and shielding.
- State what levels of radiation are considered dangerous.
- Describe the effectiveness of various personal protective equipment (PPE) for ~~radiation~~ and contamination.

-Basic Concepts -
Dose, Dose Rate, Activity, and Our Radioactive World

What is Ionizing Radiation?

Ionization - the process of removing or adding electrons to an atom



Ionization imparts energy to the body. This is called Dose.

Ionizing radiation – radiation sufficiently energetic to knock electrons out of their orbit, thus causing ionization

Definitions

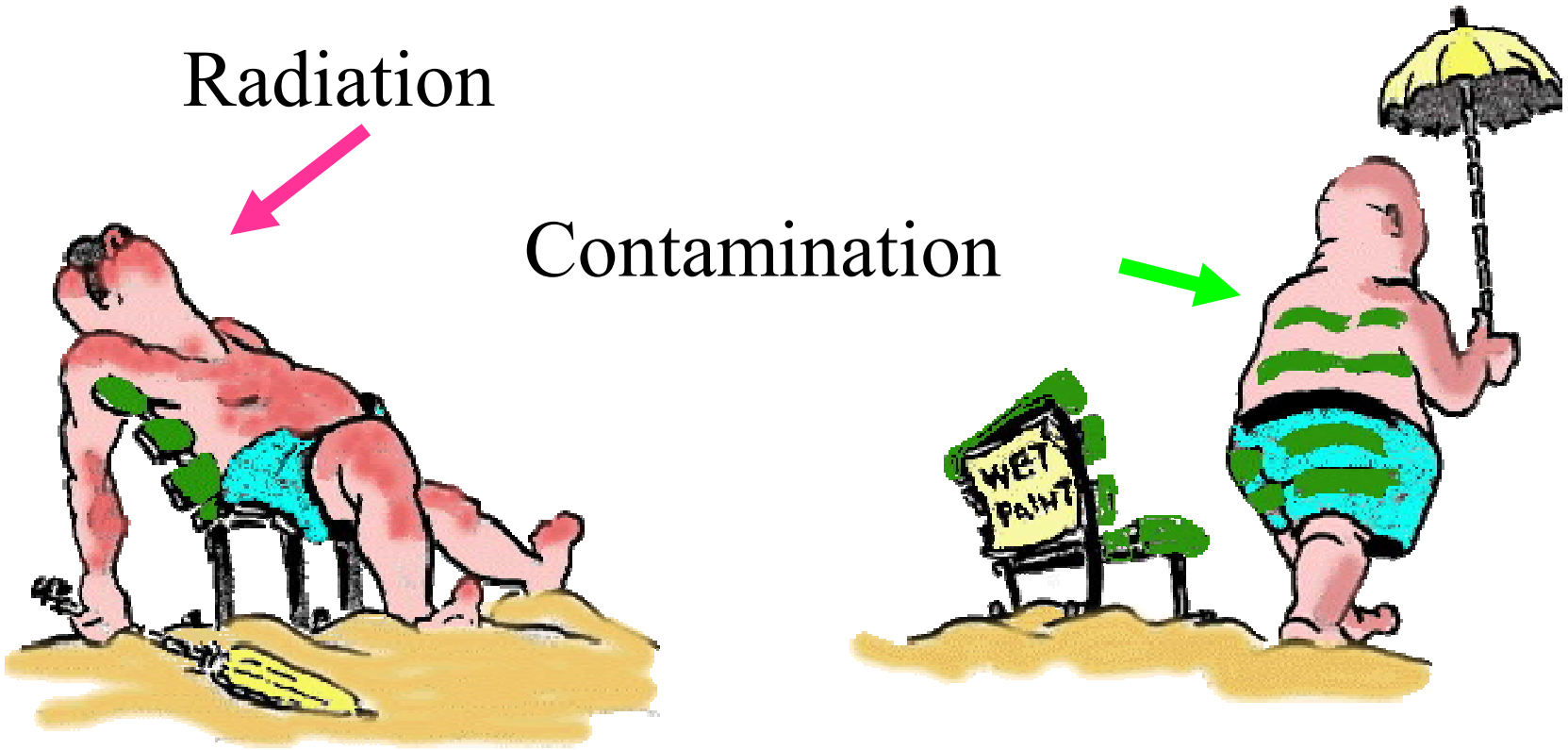
- Activity in Curies or Becquerels (SI)
  - How many disintegrations per second, relates to the number of emitted particles only.
- Exposure in Roentgens (R), mR, or μR (ionization in air at STP)
  - Measure of a charge from ionization by X-Rays or Gamma Rays
  - Outdated, but you may still see instruments with these units.
- Absorbed Dose = Energy Absorbed
  - Amount of energy absorbed by a unit mass of material (e.g. air, tissue, etc.)
  - Units of radiation absorbed dose (RAD) or Gray (SI)
- Biologically-Equivalent Dose = Absorbed Dose x Quality Factor = Risk
  - A common scale for equating relative hazard of various types of ionizing radiation in terms of equivalent risk (biological effects)
  - Units of roentgen equivalent man (REM) or Sievert (SI)
  - Quality Factor
    - Alpha = 20
    - Beta = 1
    - Gamma = 1

Activity and Dose

- Activity is purely related to the number of radioactive decays per unit time.
  - Says nothing about how the decays affect people or things
  - Some type of ionizing radiation is emitted in each decay
  - High activity doesn't imply grave danger.
- Dose describes the amount of energy and damage imparted to the body by the radiation itself.
  - Says nothing about the activity
  - The larger the dose, the greater the danger.

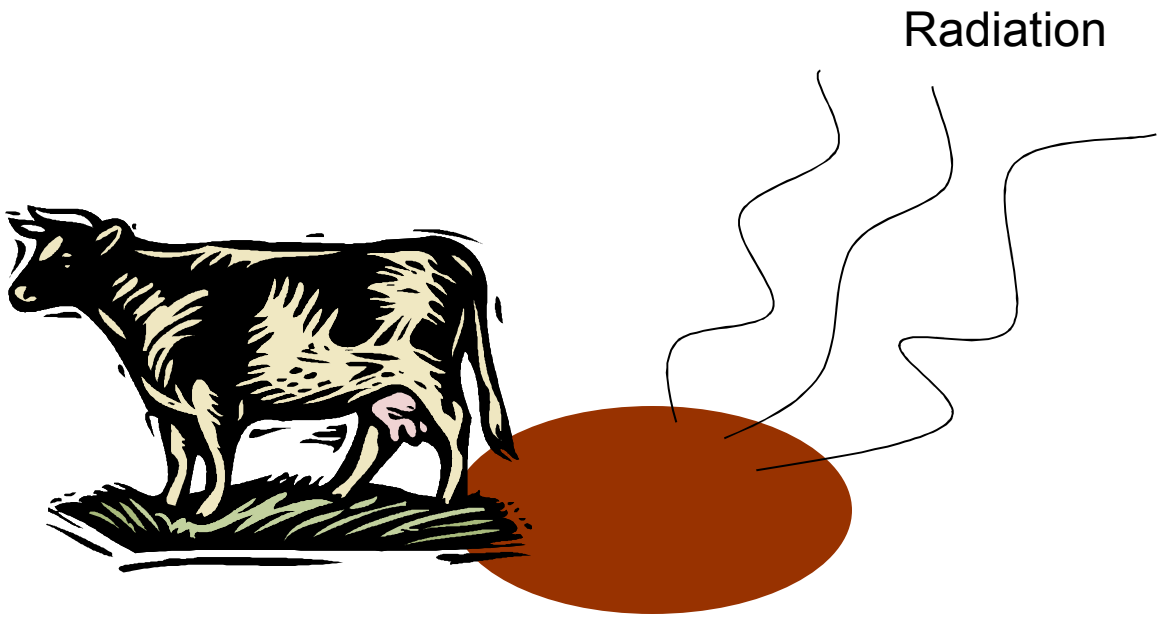
Radiation and Contamination

Exposure to radiation fields cannot result in radioactive contamination



Contamination is radioactive material where it's not wanted.

Radiation and Contamination (Another Example)



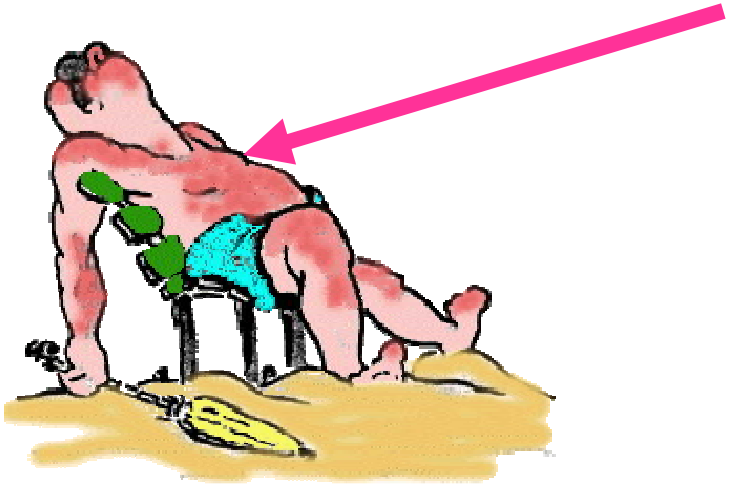
Contamination

Dose Rate and Dose

Dose Rate is simply the rate at which you are receiving a dose i.e., mrem/hr (or mSv/hr)

Dose is the amount of radiation you have received i.e., mrem (or mSv)

Energy deposited into the body = dose



Examples

Dose Rate x Time = Dose

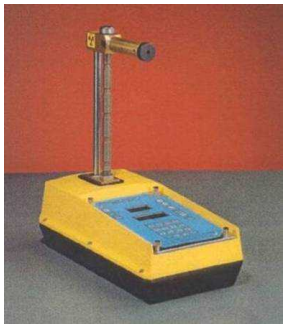
100 mrem/hr x 2 hours = 200 mrem

Stay time = maximum allowed dose ÷ dose rate

10 mrem limit ÷ 10 mrem/hour = 1 hour stay time
10 mrem limit ÷ 1000 mrem/hour = 0.1 hour (6 min) stay time

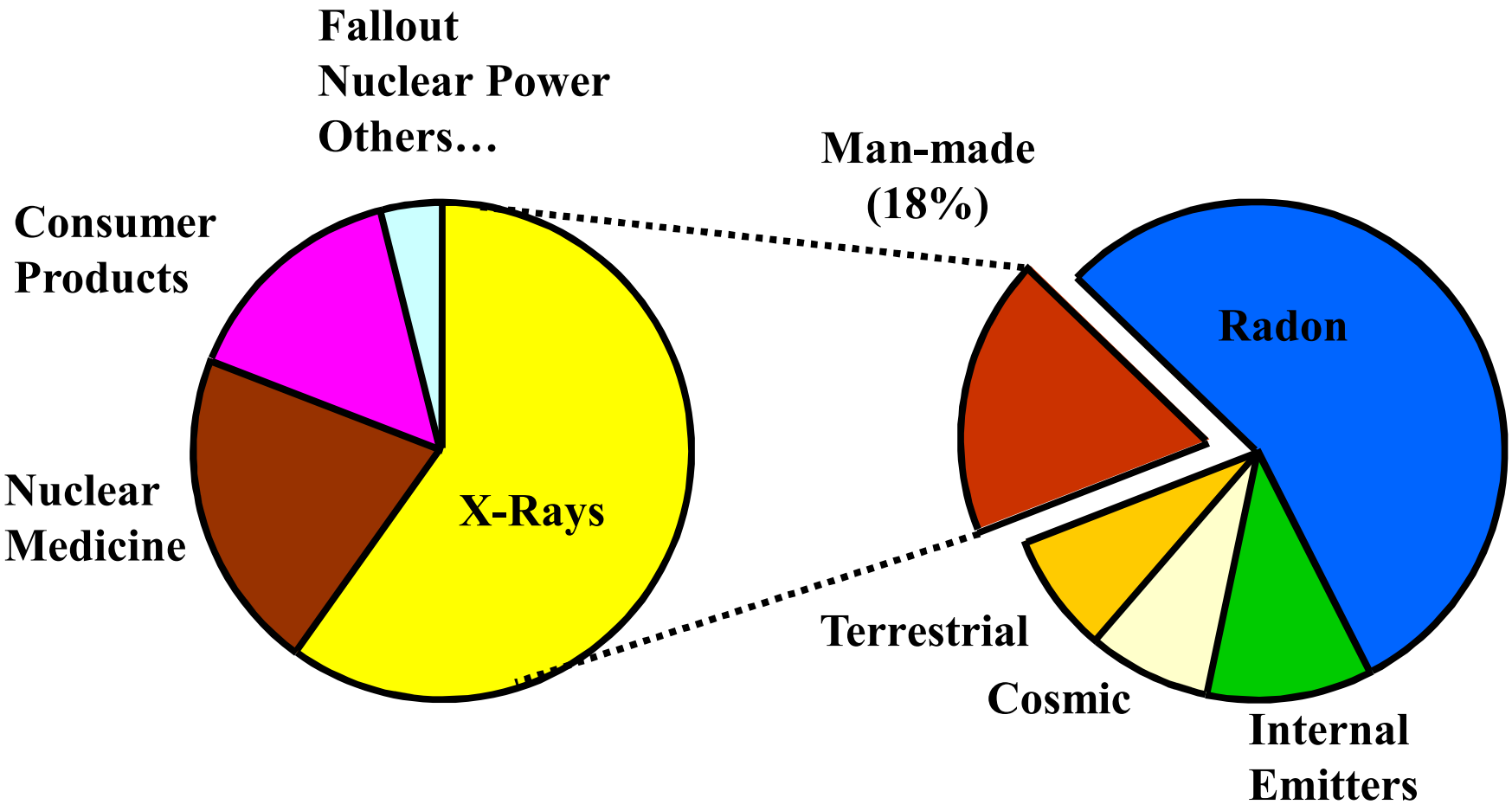
Work can be conducted in a high dose rate area if the stay time is limited!

We Live in a Radioactive World!



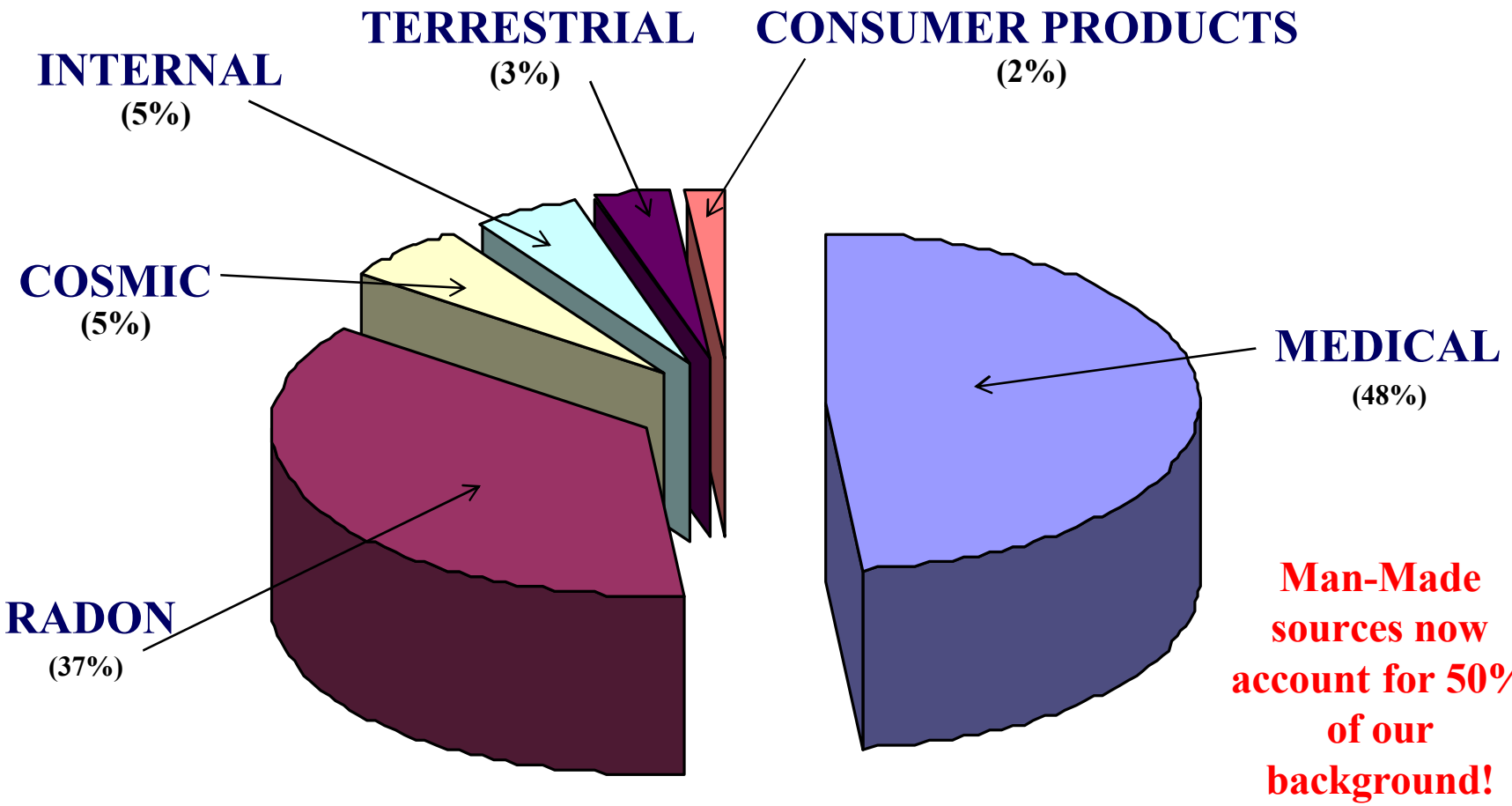
Background Radiation (NCRP 93 - 1987)

Annual Dose Equivalent: 360 mrem (3.6 mSv)



Background Radiation (NCRP 160 - 2009)

Annual Dose Equivalent: 620 mrem (6.2 mSv)



Man-Made sources now account for 50% of our background!

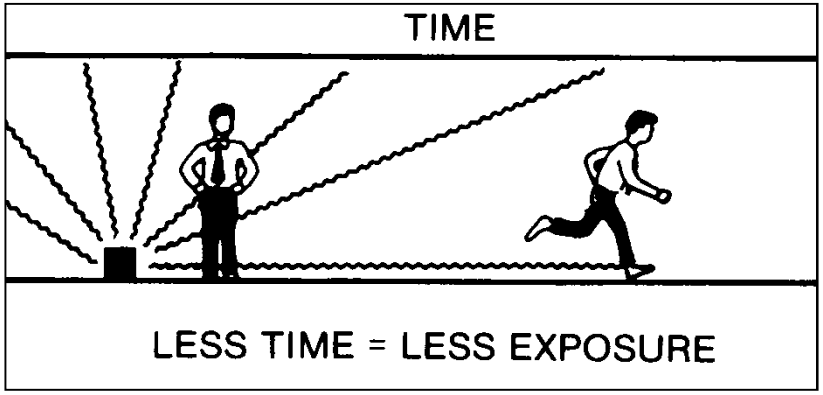
Average Dose Rates

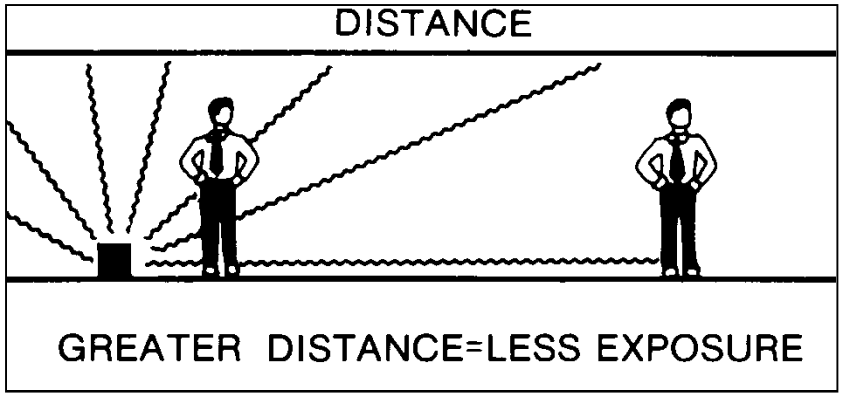
• Smoking 1.5 packs/day	8000 mrem/year
• Background	360 mrem/year
• Flight crew	170 mrem/year
• Potassium in body	39 mrem/year
• Chest x-ray	10 mrem/exam
• Consumer products	10 mrem/year
• Roundtrip flight LA to NY	2 mrem/hour
• Smoke detector	1 mrem/year

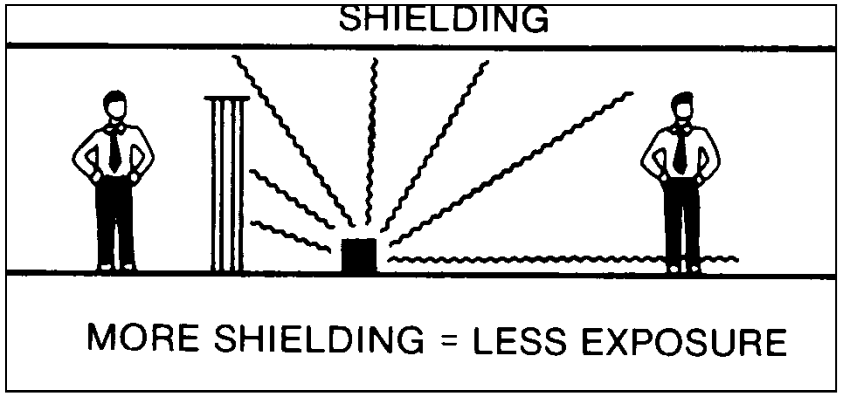
Occupational Limits	
•public	100 mrem/year
•rad worker	5000 mrem/year
•emergency	25000 mrem

- Methods of Protection -
Obtaining a Benefit while Preventing Detrimental Effects

External Radiation Protection Principles







Using these principles helps keep your dose as low as reasonably achievable (ALARA)

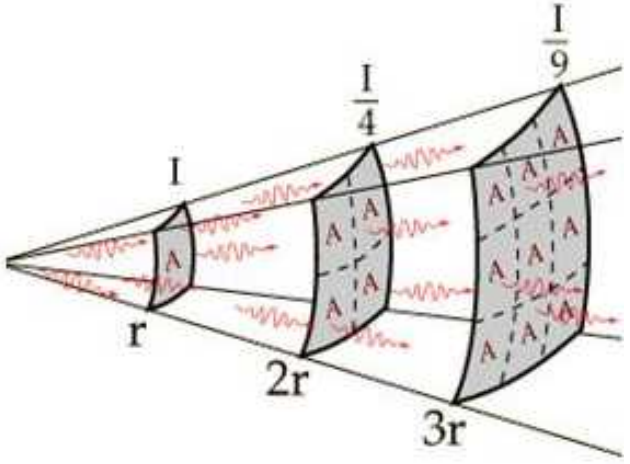
The Importance of Distance (Inverse Square Law)

- Dose rate changes with distance
- Increasing distance lowers the intensity

$$D_2 (r_2^{2)} = D_1 (r_1^2)$$

D_1 = Measured dose rate at distance r_1

D_2 = Dose rate at distance of r_2



✓ **Examples:**

D_1 = Dose rate at 1 m = 100 mrem/hour

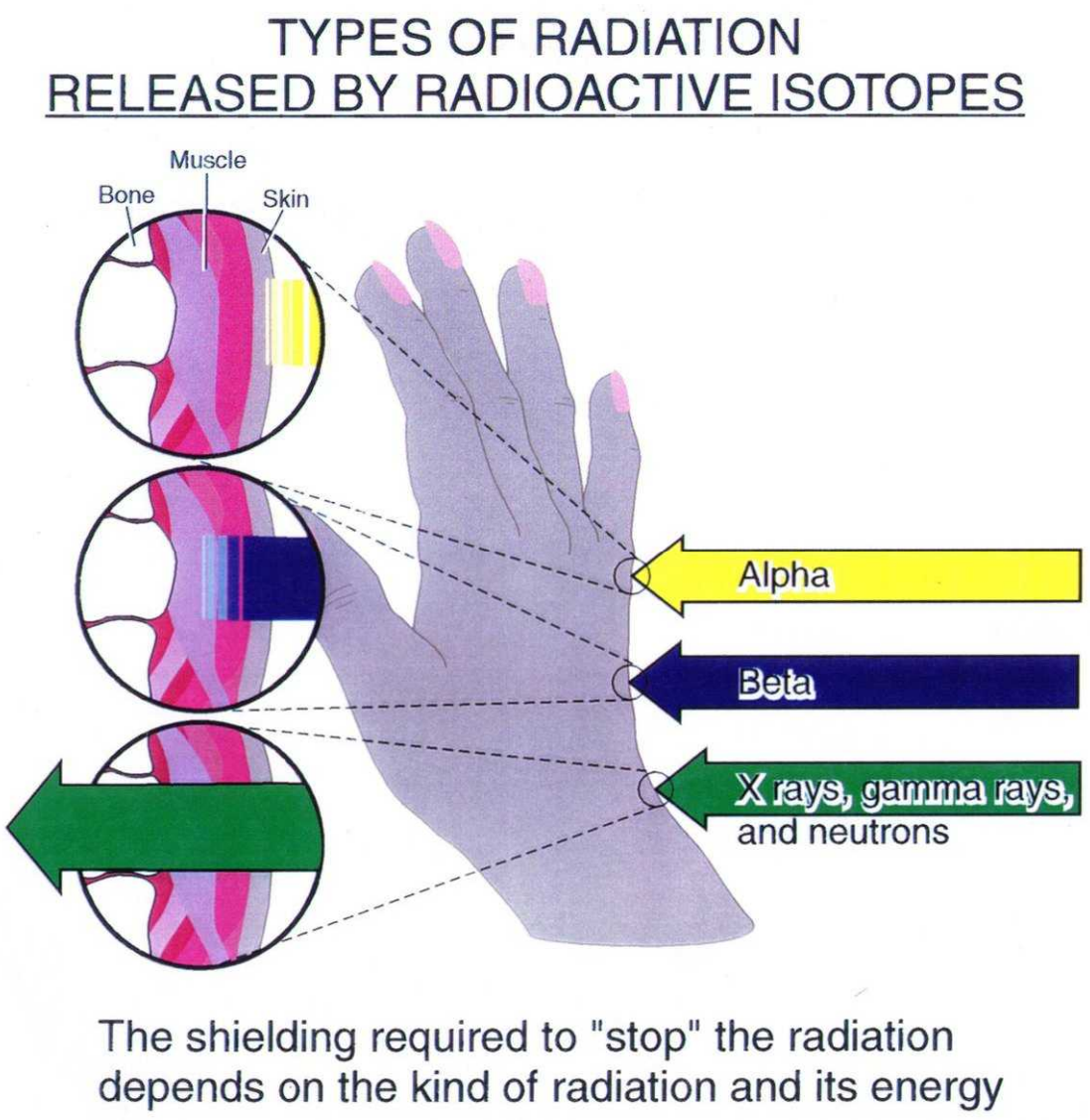
D_2 = Dose rate at 2 m = 25 mrem/hour

D_2 = Dose rate at 4 m = 6.25 mrem/hour

Maximizing Distance

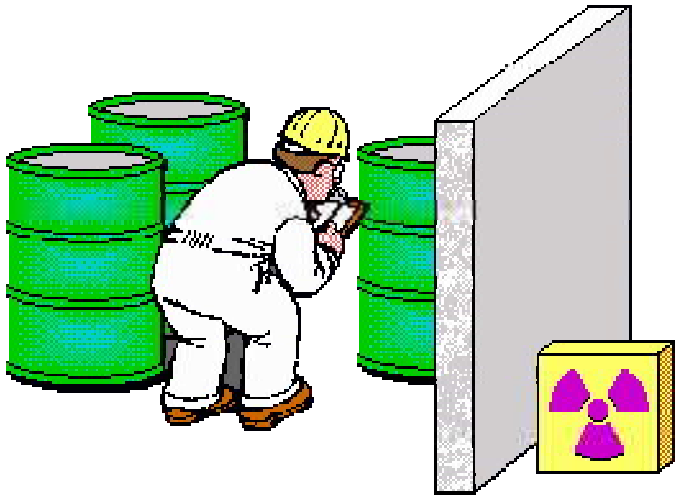
- Stay as far away from the source of radiation as possible.
- During work delays, move to lower dose rate areas.
- Use remote handling devices when possible.

Penetrating Power of Radiation



Use of Shielding

- Take advantage of permanent shielding (equipment/structures)
- Use shielded containments when available.
- Use of safety glasses to protect your eyes from beta radiation, is advisable.



- Biological Effects -
Balancing Benefits with Risks

Everyday Risks

Estimated days of life expectancy lost **as a result of the health risks associated with these daily activities.**

Activity	Avg. Est Days Lost
Unmarried Male (risky behavior)	3500 days
Cigarette Smoking (cancer)	2250 days
Unmarried Female (risky behavior)	1600 days
Coal Mining (dangerous job)	1100 days
25% Overweight (bad health risk)	777 days
Construction Work (danger)	227 days
Driving a Motor Vehicle (accident)	207 days
1.0 mSv/year for 70 years	10 days

Radiation Risks

- Chronic Radiation Dose (small dose – long time)
  - Small Dose - Long Time
  - Few Cells Affected
  - Risk: Genetic effects, cancer
- Acute Radiation Dose (large dose – short time)
  - Large Dose - Short Time
  - Many Cells Affected
  - Risk: Nausea, vomiting, burns, hair loss
- Risk management objectives
  - Prevent acute doses
  - Maintain chronic doses ALARA

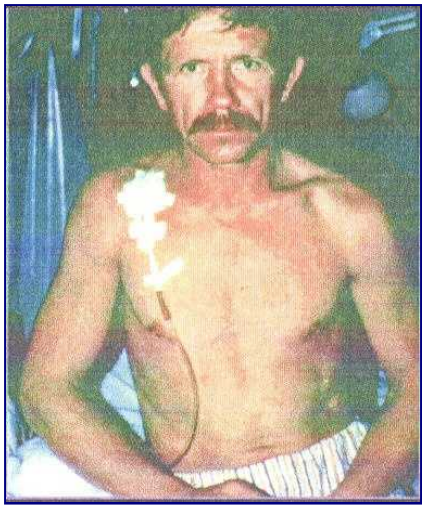
Acute Doses – Whole Body

Radiation Dose Whole Body (rem)	Immediate Expected Effects
15-50	Blood – microscopic, no symptoms, changes in blood cell counts
100-200	Vomiting in 5 to 10% within 3 hours, with fatigue and loss of appetite. Moderate blood changes. Recovery will occur within a few weeks with the exception of the blood forming system.
200-600	For 300 rem or more, all exposed individuals will exhibit vomiting within 2 hours or less, in conjunction with diarrhea, weakness, fever, and subcutaneous bleeding; severe blood changes, accompanied by hemorrhage and infection; and loss of hair after 2 weeks. Recovery in 20% to 100% of individuals can be expected within 1 month to a year for those who receive a dosage less than 400 rem. For individuals who receive greater than 400 rem, it is expected that 50% will die. This death rate threshold is defined as lethal dose 50, i.e. LD50.
600-1000	Vomiting within 1 hour, severe blood changes, diarrhea, weakness, fever, and subcutaneous bleeding, hemorrhage, infection, and loss of hair. From 80 to 100 percent of exposed individuals will succumb from 10 days to 2 months. Those who survive will be convalescent over a long period.
> 1000	There are severe effects on the central nervous system. Symptoms include fever, convulsions, and lethargy, which appear immediately. Death occurs within a day or two from central nervous system failure.

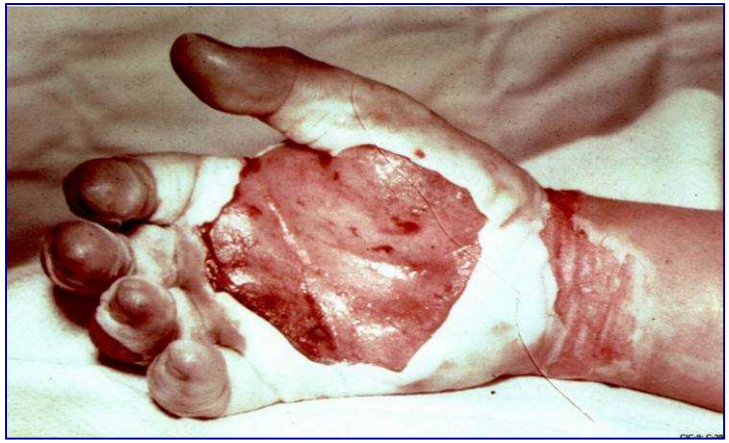
Acute Doses - Localized

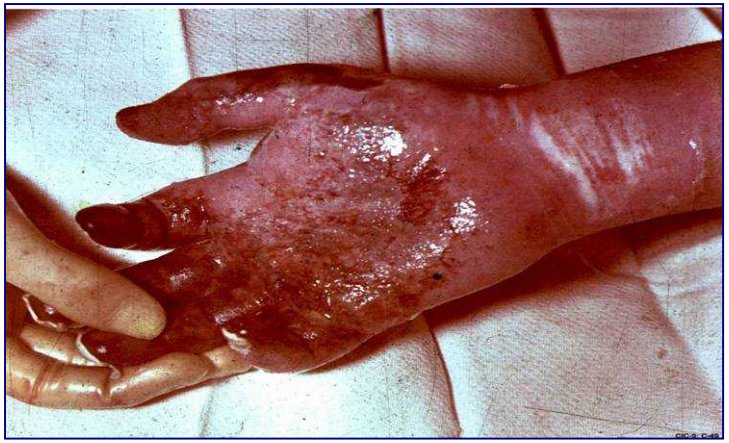
Fetus	**Significant probability of malformation if irradiated early in pregnancy**	**10 to 20 rad**
Gonads	**Sterility for 1 to 2 yr**	**250 rad**
	Permanent sterility	**600 rad**
Eye	**Change in optic lens**	**200 rad**
	Clinically significant cataract	**600 rad**
Skin	**Reddening**	**300 rad**
	Raw, moist area	**1500 rad**
	Ulceration, slow healing	**5000 to 7000 rad**
Fingers	**Cell death, amputation**	**10,000 rad**

Acute Exposure - Irradiation Facility



Acute Exposure - Criticality

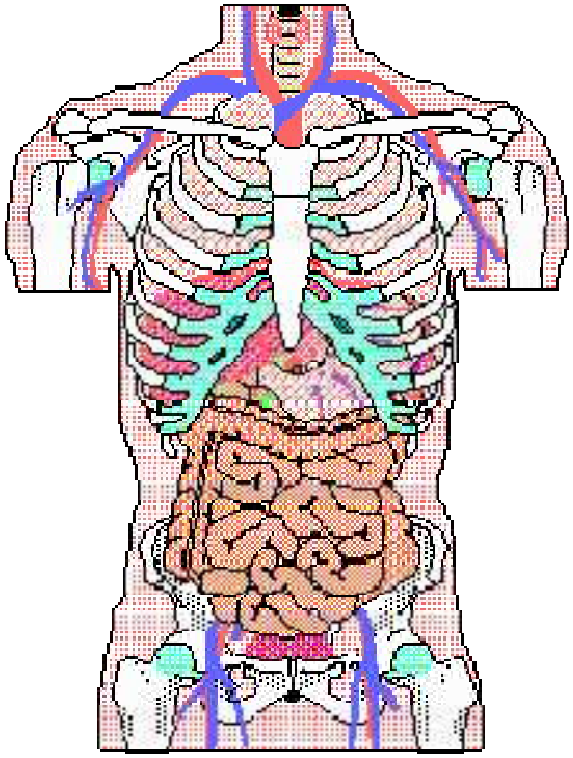




Goiania Victim – Oncology Clinic

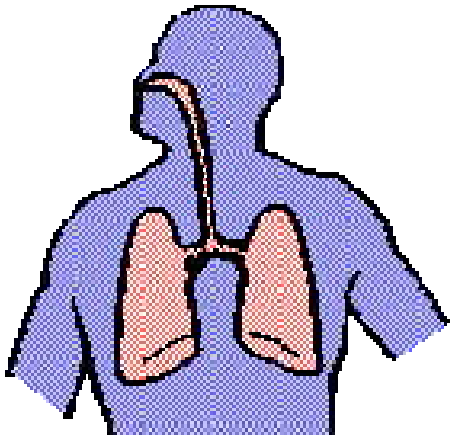
- Minimizing Internal Hazards -
Personal Protective Equipment (PPE)

Internal Hazards

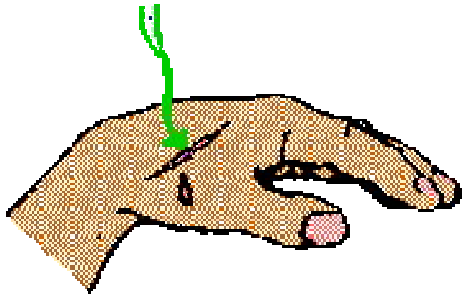


- Internal dose is a result of radioactive material being taken into the body.
- Cannot use external ALARA techniques of
  - Distance
  - Shielding
- Minimize internal dose by:
  - Minimizing time
    - Exposure
    - Use of chelating agents (minimal)
  - Use of PPE

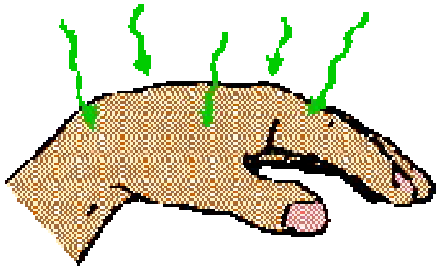
Pathways for Radioactive Material



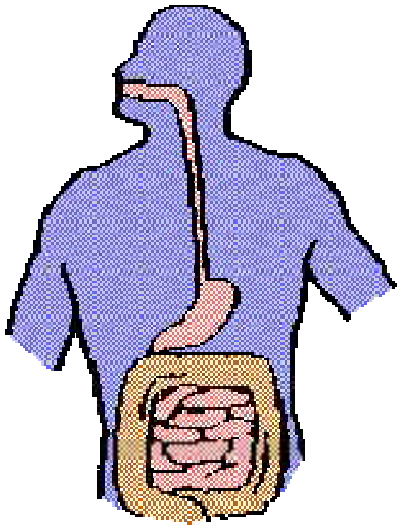
Inhalation



Injection



Absorption



Ingestion

Possible Treatments for Intakes of Radioactive Material

Prussian Blue
(Cesium-137)

- Chemically binds **cesium**, facilitating excretion from the body and preventing absorption by the body.
- Reduces the biological half-life from 115 to 40 days.
- Supplied through a doctor in 500-mg capsules.
- Usually taken **3-4 times daily for 150 days**.

Potassium Iodide
(Iodine-131)

- Taken only if radioactive **iodine** is involved in nuclear incident.
- Protects person's thyroid by saturating it with iodine, thus reducing the likelihood of absorption of any radioactive iodine.

Aluminum Phosphate
(Strontium-90)

- Minimizes the risk of radiation induced bone cancer.
- May improve excretion of **strontium** from the body.
- Oral administration can reduce absorption by up to 85%.

CA-ZN DTPA
(Plutonium)
(Americium)

- Clinical use for de-contamination of **plutonium and americium**.
- Patient with more than 1 mCi of Americium had 99% total body burden removed with **prolonged therapy over 4 years**.

For Ingestion of Radioactive Material Only!

Types of Contamination

- *Fixed contamination* is contamination that cannot be readily removed from surfaces (PPE not needed).

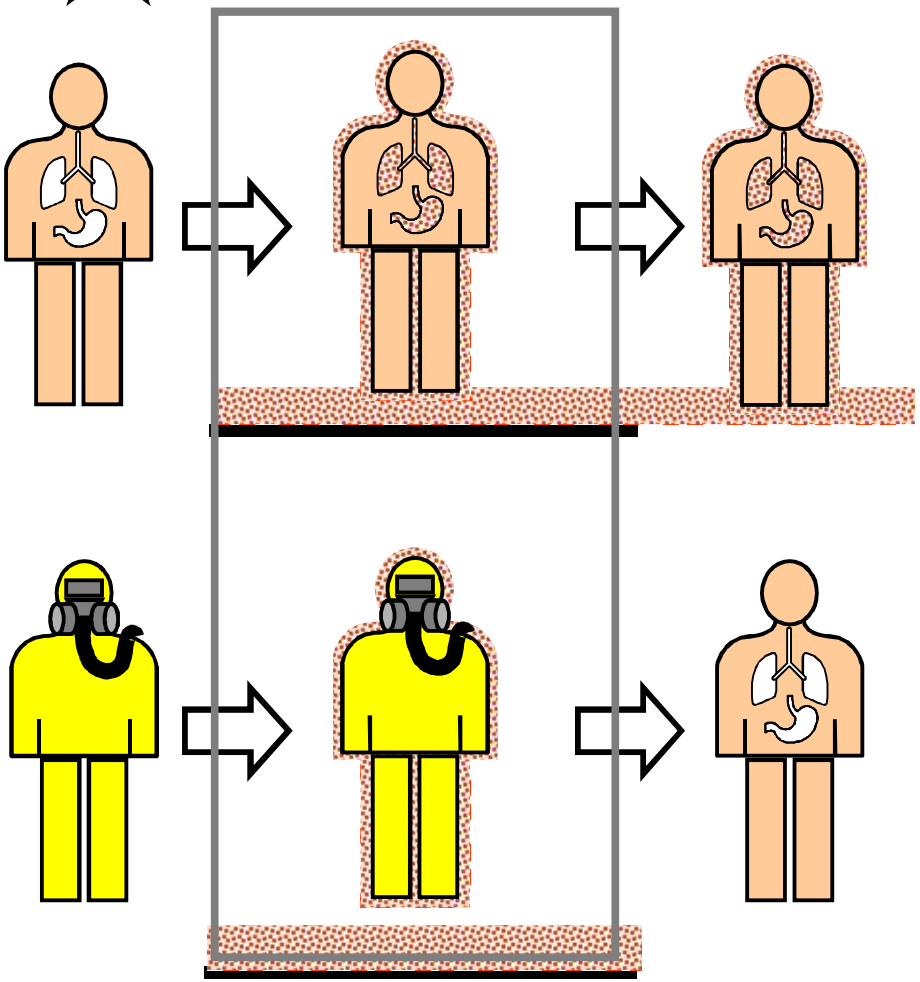
- *Removable/transferable contamination* is contamination that can be readily removed from surfaces (PPE is effective).

- *Airborne contamination* is contamination suspended in air (PPE is effective)

What PPE Does

PPE = Personal Protective Equipment

PPE prevents contaminants from entering the body



Without PPE

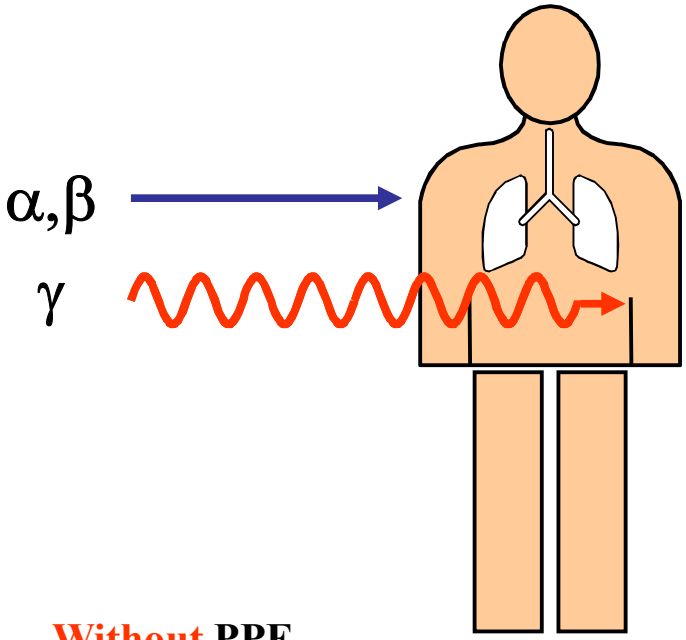
- External exposure
- Internal exposure
- Contamination spreads

With PPE

- External exposure only
- Minimizes contamination spreading
- PPE is radioactive waste

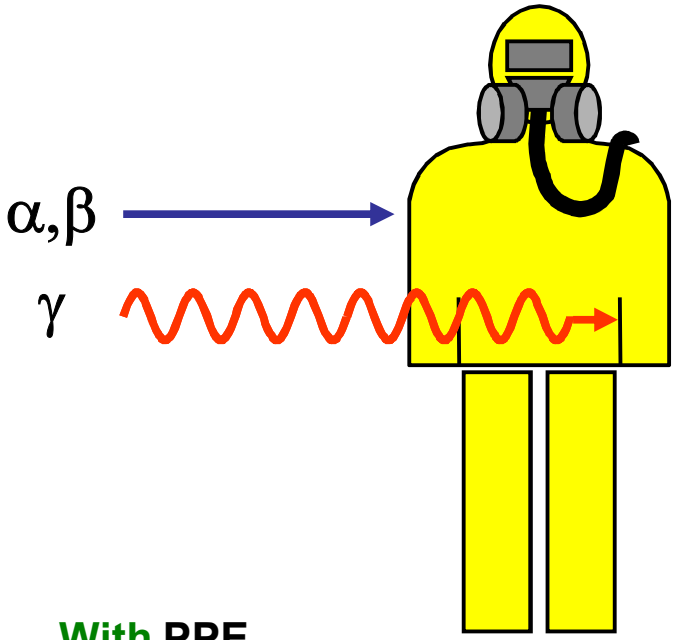
What PPE Doesn't Do

PPE does not reduce external exposure!



Without PPE

- gammas penetrate body
- alphas stopped by skin & clothes; may be inhaled
- betas penetrate muscle; may be inhaled

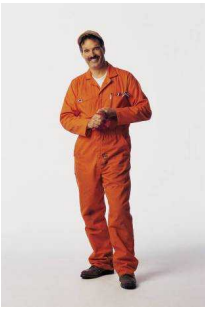


With PPE

- gammas penetrate body
- alphas stopped by suit and filtered by respirator
- betas (some) stopped by suit and filtered by respirator

Contamination Control

- Wear PPE in areas that are possibly contaminated e.g.:
  - Gloves
  - Shoe covers
  - Respirators (if needed)
  - Lab coat / Tyvek suit



- Remove PPE and monitor for contamination when exiting contaminated or potentially contaminated areas.
- If contamination is detected
  - Decontaminate skin with mild soap and lukewarm water
  - Monitor affected area(s) again.
  - Repeat, if necessary.

Radiation survey probes for contamination monitoring

Decontamination

- General considerations
  - Contamination concentration
  - Contamination type
  - Size of the area or the object
  - Surface structure
  - Decontamination methods and agent(s)

- Generic procedures
  - Tape press or sticky back substrate
  - Warm water or household soap solutions
  - 3M ScotchBrite pad in tray
  - BAG IT, POST IT and MONITOR IT.
  - Package as radioactive waste as necessary

Health Physics Kit

- Contamination Detection
  - Alpha probe
  - Beta probe
- Exposure Detection
  - Gamma probe
  - Neutron probe
  - Dosimetry