Principles of Radiation Science

(incorporating information from various sources, incl. WVNS)

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CTF
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18760_1

Presentation Overview

- Basic radiation discussion
- Biological effects of radiation
- Managing worker exposure at the WVDP

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Health Effects of Radiation: will apply to any human exposure to ionizing radiation, including:

- **Naturally occurring radiation**
- **Radiation from human activities such as:**
  - **Waste sites**
  - **Power plants**
  - **Weapons testing**

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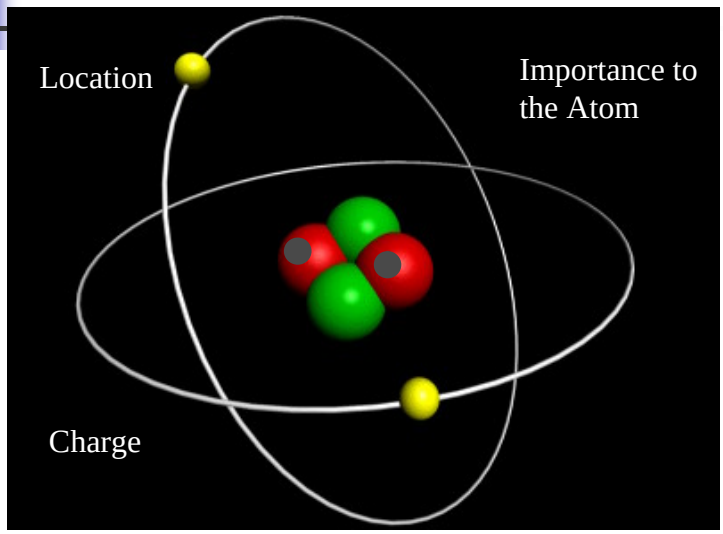
The Parts of the Atom…



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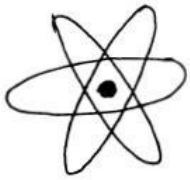
Atoms (if you could magnify):



Some atoms are **stable**

Some atoms are **unstable** (radioactive): --Natural

--Manmade

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Radiological Terminology

- Radioactivity: the process whereby unstable atoms try to become stable by emitting radiation
- Radiation: energy in the form of waves or particles given off from an unstable atom
- Radioactive Material: anything that contains unstable atoms which give off radiation
- Radioactive Contamination: radioactive material in an unwanted or undesignated place
- Decay: process of radioactive atoms releasing radiation over a period of time and becoming stable (also called disintegration)
- Half Life: the time it takes for a group of atoms to decay to half of their original activity

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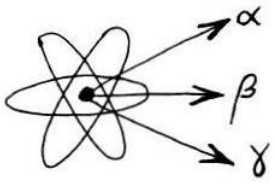
RADIOACTIVE **EMISSION:**



Alpha particle

Beta particle

Gamma ray

37 billion/second = **1 Curie**

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RADIATION **EXPOSURE** or **DOSE:**

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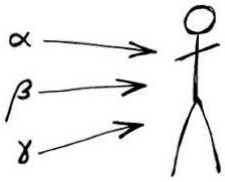
Beta particle

Gamma ray



1 rem = a measure of exposure or dose

1/1000 of 1 rem = 1 millirem (1 mrem)

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Penetrating power in living tissue:

ALPHA: Less than 1 millimeter

BETA: Several millimeters

GAMMA: Very penetrating

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INTERNAL EXPOSURE:

- Ingested
- Inhaled

For example:

- Potassium-40
- Radioactive iodine
- Strontium-90
- Radon

Important difference between RADIOACTIVITY and RADIOACTIVE MATERIAL

EXPOSURE PATHWAY = how radioactive material gets into the body

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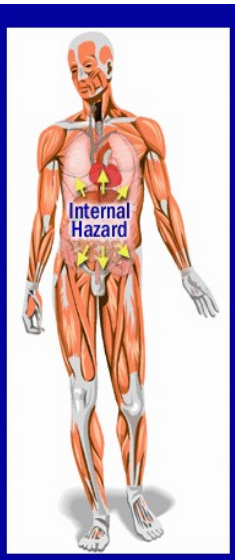
Ionizing Radiation

α Alpha Particle

Physical Characteristics	- Large mass - +2 charge (2 protons and 2 neutrons)
Range	- Very short (about 1-2 inches in air) - Deposits a large amount of energy in a short distance of travel
Shielding	- Few inches in air - Sheet of paper - Dead layer of skin (outer layer)
Biological Hazard	- Internal hazard - Internally the source of alpha radiation is in close contact with body tissue. It can deposit large amounts of energy in a small amount of body tissue
Sources at the WVDP	- Americium-241 (Am241) - Plutonium-239 (Pu239) - Uranium-233, 235 (U233, U235)



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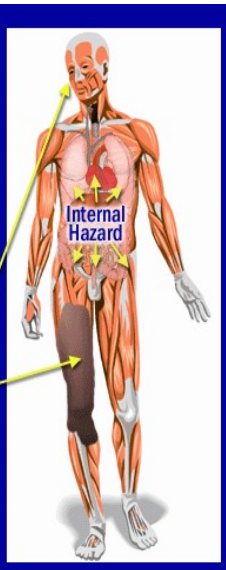
Ionizing Radiation

β Beta Particle

Physical Characteristics	- Small mass - -1 charge (negative 1)
Range	- Short distance (about 10 feet in air)
Shielding	- Plastic - Glass - Aluminum foil - Safety glasses
Biological Hazard	- Internal hazard (this is due to short range) - Externally, may be hazardous to skin and eyes
Sources at the WVDP	- Cesium-137 (Cs137) - Strontium-90 (Sr90) - Tritium



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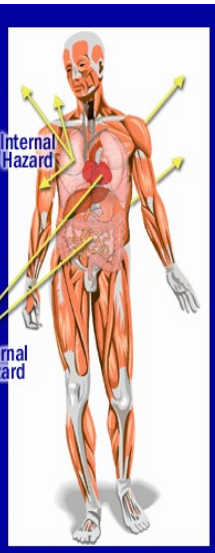
Ionizing Radiation

γ Gamma Ray

Physical Characteristics	- No mass - No charge - Electromagnetic wave or photon - Very similar to x-rays (difference is place of origin)
Range	- Range in air is very far - It will easily go several hundred feet - Very high penetrating power since it has no mass and no charge
Shielding	Dense material such as: - Concrete - Steel - Lead
Biological Hazard	- Whole body exposure - The hazard may be external and/or internal. This depends on whether source is inside or outside body
Sources at the WVDP	- Cesium-137 (Cs 137) - Cobalt-60 (Co 60)



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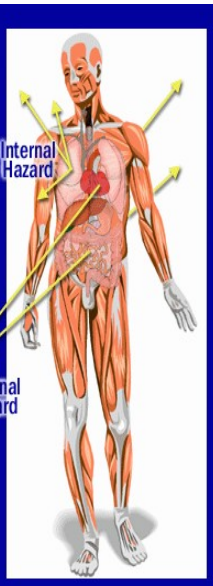
Ionizing Radiation

η Neutron Particle

Physical Characteristics	- No charge - Has mass
Range	- Range in air is very far - Easily can go several hundred feet - High penetrating power due to size and lack of charge (difficult to stop)
Shielding	- Water - Concrete - Plastic (high hydrogen content)
Biological Hazard	- Whole body exposure - The hazard may be external or internal. This depends on whether the source is inside or outside the body
Sources at the WVDP	- Uranium-233 (U233) - Uranium- 235 (U235) - Plutonium-239 (Pu239)



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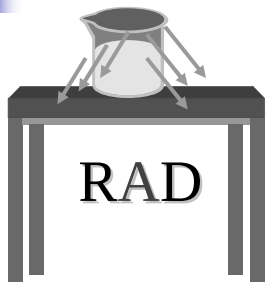
Measurement Terminology



Any Radiation in **any** material

Exposure to soft tissue in **Man**
RAD x QF = Rem

Roentgen

Gamma in air

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Dose & Dose Rate

Dose is the amount of exposure received

Bob picked up 5 mRem

Dose rate is how quickly it is delivered

The area radiation level is 10 mRem/hr

How long was Bob in the area ??

30 min

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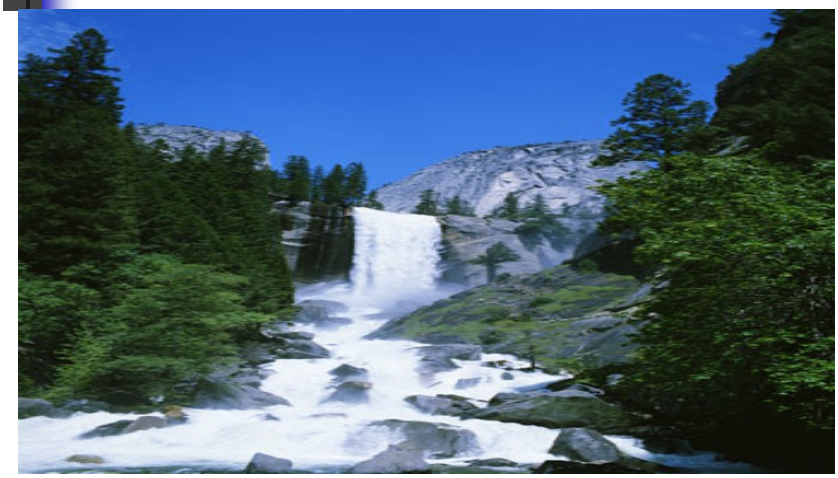
Sources of Radiation in Our Environment



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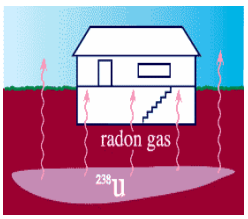
Natural Radiation Sources

Cosmic

Internal



Radon

Terrestrial

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Man-Made Radiation Sources

- Medical radiation
- Tobacco Products
- Building Materials

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Radiological Dose from "Everyday" Sources

Smoke detector	1 mrem/yr
Building masonry	7 mrem/yr
Cigarettes (1-1/2 pack/day)	1,300 mrem/yr

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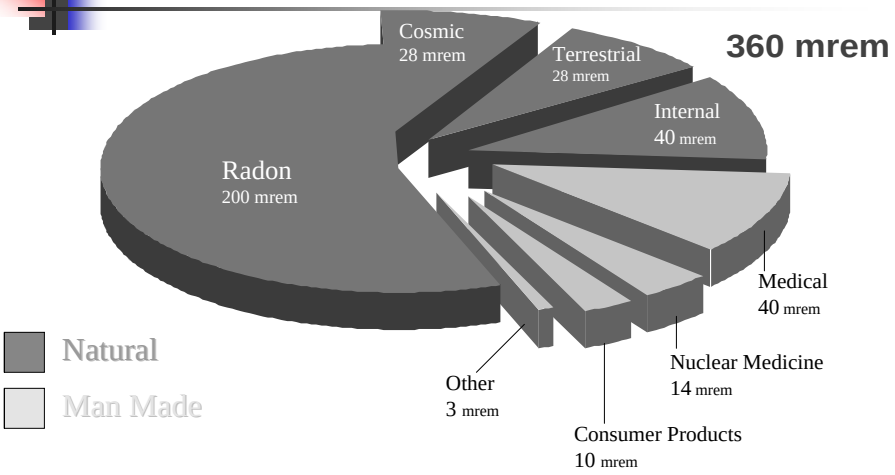
Average Annual Dose



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Biological Effects

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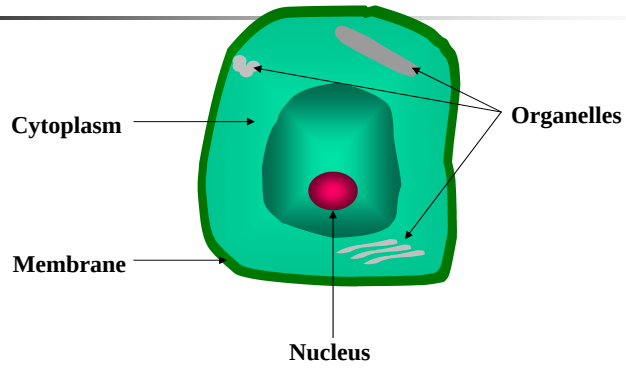
Effects of Radiation on Cells



- Ionization of the atoms that make up the cells is the cause of damage to the body.

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Cell Damage From Radiation Exposure

- No damage
- Cells damaged but repair and operate normally
- Cells damaged and operate abnormally
- Cells die as a result of damage

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Acute Exposure

- Large dose of radiation received in a short period of time
- Depending on amount, may result in temporary blood changes, radiation sickness, (loss of hair, vomiting and diarrhea) and even death
- Example: Accident condition

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Chronic Exposure

- Low-level of radiation exposure received over a long period of time, with no obvious effect
- Example: Natural background
- Associated health effect: Cancer

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Genetic Effects

Somatic effects

Affect the individual

- Prompt
- Delayed
  - Cancer
  - Cataracts
  - Life shortening

Heritable Effects

affect the offspring

– observed in plants and animals

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Factors Affecting Biological Damage

- Total dose
- Dose rate
- Radiation type
- Area of exposure
- Cell sensitivity

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Exposure Limits at the WVDP

- Worker exposure limits will be specific to work being performed
- Three dose limits on site
  - 100 mrem: Non-badged & general public
  - 500 mrem: Support staff
  - 1000 mrem: Operations (workers)

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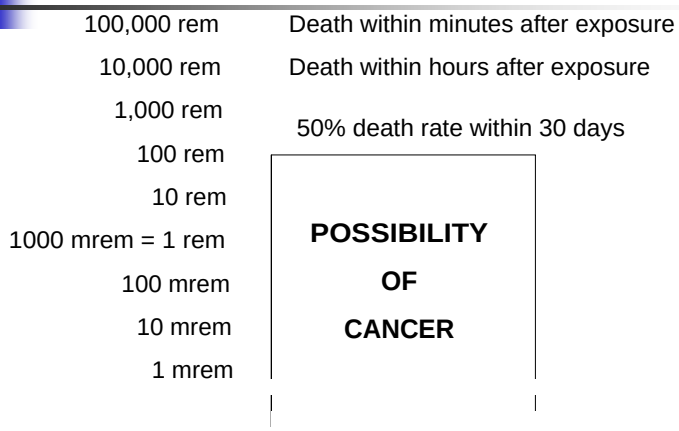
For radiation exposure, how does the EFFECT vary with the DOSE?



At HIGH doses: The higher the dose, the more SEVERE the effect.

At LOW doses: The higher the dose, the more PROBABLE the effect.

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TABLE 4-2 Excess Cancer Mortality Estimates and Their Statistical Uncertainty—Lifetime Risks per 100,000 Exposed Persons[a]

	Male			Female		
	Total	Nonleukemia[b]	Leukemia[c]	Total	Nonleukemia	Leukemia
Single exposure to 0.1 Sv (10 rem)	770	660	110	810	730	80
90% confidence limits[d]	540–1,240	420–1,040	50–280	630–1,160	550–1,020	30–190
Normal expectation	20,510	19,750	760	16,150	15,540	610
% of normal	3.7	3.3	15	5	4.7	14
Total years of life lost	12,000			14,500		
Average years of life lost per excess death	16			18		
Continuous lifetime exposure[e] to 1 mSv/y (0.1 rem/y)	520	450	70	600	540	60
90% confidence limits[d]	410–980	320–830	20–260	500–930	430–800	20–200
Normal expectation	20,560	19,760	790	17,520	16,850	660
% of normal	2.5	2.3	8.9	3.4	3.2	8.6
Total years of life lost	8,100			10,500		
Average years of life lost per excess death	16			18		
Continuous exposure[f] to 0.01 Sv/y (1 rem/y) from age 18 until age 65	2,880	2,480	400	3,070	2,760	310
90% confidence limits[d]	2,150–5,460	1,670–4,560	130–1,160	2,510–4,580	2,120–4,190	110–910
Normal expectation	20,910	20,140	780	17,710	17,050	650
% of normal	14	12	52	17	16	48
Total years of life lost	42,200			51,600		
Average years of life lost per excess death	15			17		

[a] Based on an equal dose to all organs and the committee's preferred risk models—estimates rounded to nearest 10.
[b] Sum of respiratory, breast, digestive, and other cancers.
[c] Estimates for leukemia contain an implicit dose rate reduction factor.
[d] Additional sources of uncertainty are discussed in Annex 4F.
[e] A dose rate reduction factor has not been applied to the risk estimates for solid cancers.

BEIR V

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TABLE ES-1 The Committee's preferred estimates of the lifetime attributable risk (LAR) of incidence and mortality for all solid cancers and for leukemia with 95% subjective confidence intervals. Number of cases or deaths per 100,000 exposed persons.

	All solid cancer		Leukemia	
	Males	Females	Males	Females
Excess cases (including non-fatal cases) from exposure to 0.1 Gy	800 (400, 1600)	1300 (690, 2500)	100 (30, 300)	70 (20, 250)
Number of cases in the absence of exposure	45,500	36,900	830	590
Excess deaths from exposure to 0.1 Gy	410 (200, 830)	610 (300, 1200)	70 (20, 220)	50 (10, 190)
Number of deaths in the absence of exposure	22,100	17,500	710	530

BEIR VII

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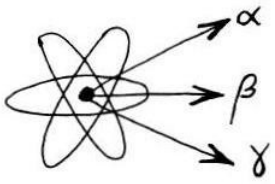
RADIOACTIVE **EMISSION:**



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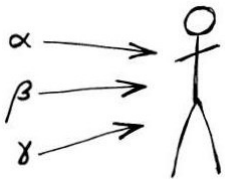

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