


Principles of Radiation Science

(incorporating information from various sources, incl. WVNS)

Ray Vaughan
CTF
July 26, 2006

18760_1



Presentation Overview

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

18760_2



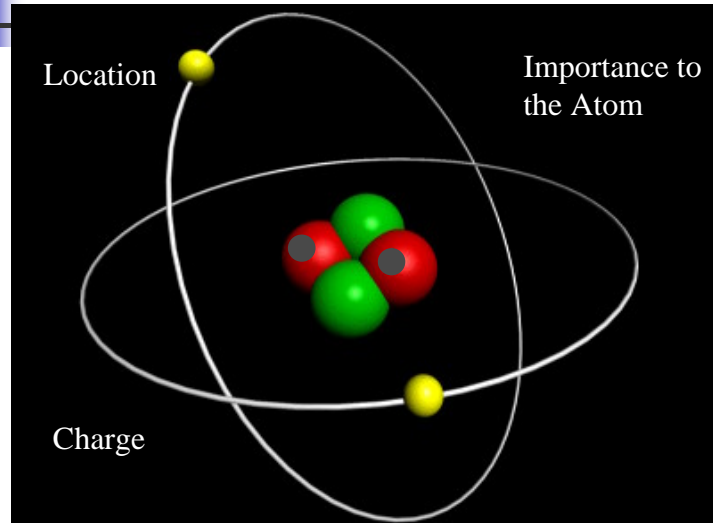
Health Effects of Radiation: will apply to any human exposure to ionizing radiation, including:

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

18760_3



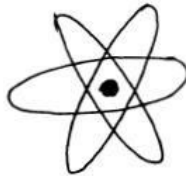
The Parts of the Atom...



18760_4



Atoms (if you could magnify):



Some atoms are **stable**

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

- Natural
- Manmade

18760_5



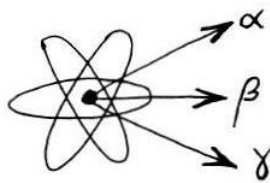
Radiological Terminology

- **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 undesigned 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

18760_6



RADIOACTIVE EMISSION:



Alpha particle

Beta particle

Gamma ray

37 billion/second = **1 Curie**

18760_7

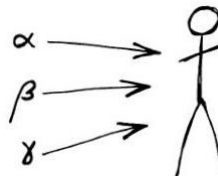


RADIATION EXPOSURE or DOSE:

Alpha particle

Beta particle

Gamma ray



1 rem = a measure of exposure or dose

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

18760_8



Penetrating power in living tissue:

ALPHA: Less than 1 millimeter

BETA: Several millimeters

GAMMA: Very penetrating

18760_9



INTERNAL EXPOSURE:

- Ingested
- Inhaled



For example:

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

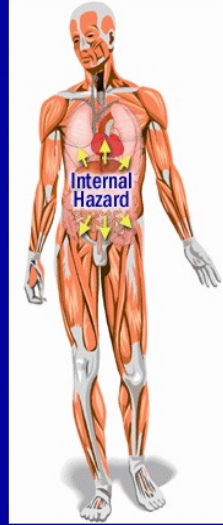
Important difference between RADIOACTIVITY and RADIOACTIVE MATERIAL
EXPOSURE PATHWAY = how radioactive material gets into the body

18760_10

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)

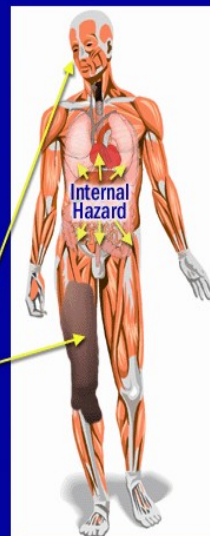


18760_11

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



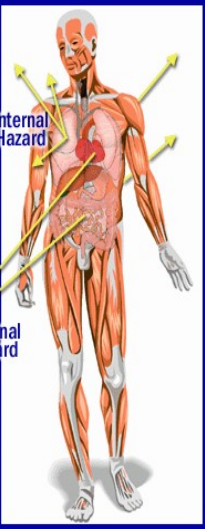
18760_12

Ionizing Radiation




γ Gamma Ray

Physical Characteristics	<ul style="list-style-type: none"> - No mass - No charge - Electromagnetic wave or photon - Very similar to x-rays (difference is place of origin)
Range	<ul style="list-style-type: none"> - 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: <ul style="list-style-type: none"> - Concrete - Steel - Lead
Biological Hazard	<ul style="list-style-type: none"> - Whole body exposure - The hazard may be external and/or internal. This depends on whether source is inside or outside body
Sources at the WWD	<ul style="list-style-type: none"> - Cesium-137 (Cs 137) - Cobalt-60 (Co 60)



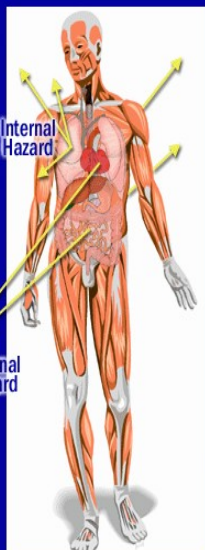
18760_13

Ionizing Radiation



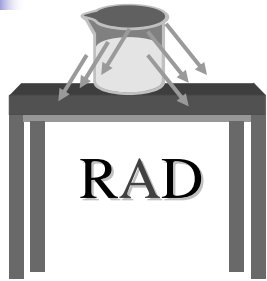
n Neutron Particle

Physical Characteristics	<ul style="list-style-type: none"> - No charge - Has mass
Range	<ul style="list-style-type: none"> - 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	<ul style="list-style-type: none"> - Water - Concrete - Plastic (high hydrogen content)
Biological Hazard	<ul style="list-style-type: none"> - 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 WWD	<ul style="list-style-type: none"> - Uranium-233 (U233) - Uranium-235 (U235) - Plutonium-239 (Pu239)



18760_14

Measurement Terminology



Any Radiation in any material



Exposure to soft tissue in Man
 $\text{RAD} \times \text{QF} = \text{Rem}$

Roentgen
Gamma in air

18760_15

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

18760_16

Sources of Radiation in Our Environment



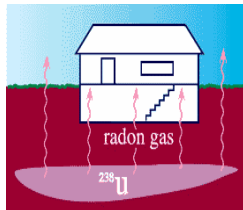
18760_17

Natural Radiation Sources

Cosmic



Internal



Radon



Terrestrial

18760_18

Man-Made Radiation Sources

- Medical radiation
- Tobacco Products
- Building Materials



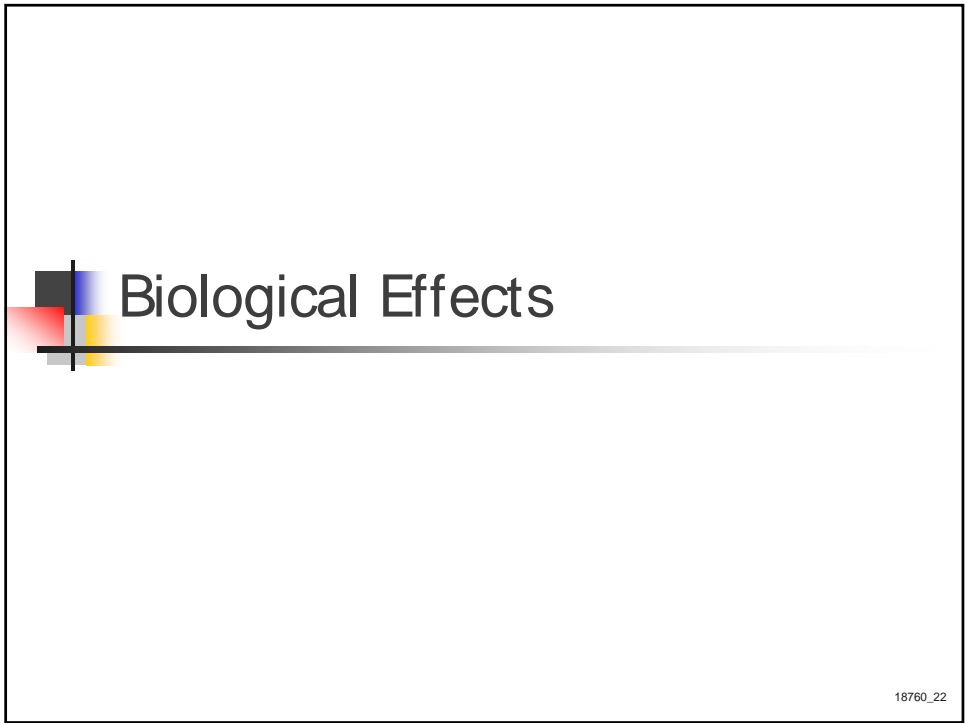
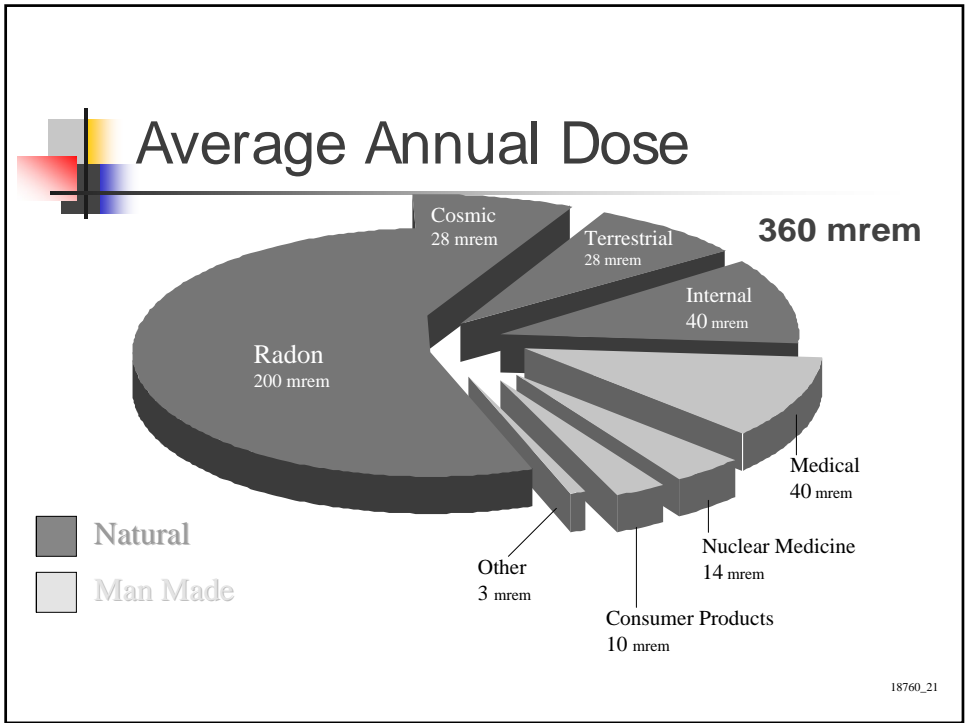
18760_19

Radiological Dose from “Everyday” Sources

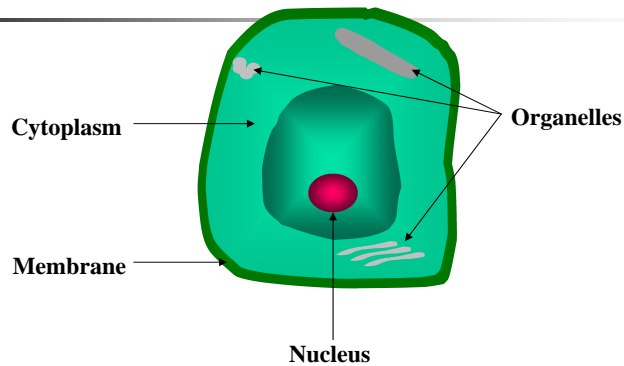
- Smoke detector 1 mrem/yr
- Building masonry 7 mrem/yr
- Cigarettes (1-1/2 pack/day) 1,300 mrem/yr



18760_20



Effects of Radiation on Cells



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

18760_23

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

18760_24

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

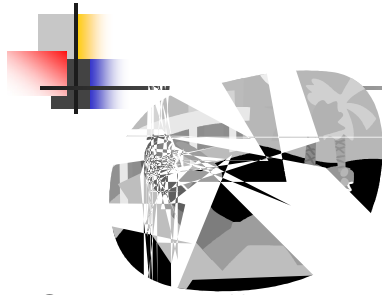


18760_25

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

18760_26



Somatic effects

Affect the individual

- Prompt
- Delayed
 - Cancer
 - Cataracts
 - Life shortening

Heritable Effects

affect the offspring

- observed in plants and animals

18760_27

Factors Affecting Biological Damage

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

18760_28



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)

18760_29



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

100,000 rem	Death within minutes after exposure
10,000 rem	Death within hours after exposure
1,000 rem	50% death rate within 30 days
100 rem	POSSIBILITY OF CANCER
10 rem	
1000 mrem = 1 rem	
100 mrem	
10 mrem	
1 mrem	

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

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

18760_30



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

	Male		Female	
	Total	Nonleukemia ^b	Leukemia ^c	Total
<i>Single exposure to 0.1 Sv (10 rem)</i>				
70% confidence limits ^d	540–2,240	420–1,040	50–280	430–1,160
90% confidence limits ^d	550–1,020	30–190		
Normal expectation	20,510	19,750	760	16,150
% of normal	3.7	3.3	15	5
Total years of life lost	12,000			14,500
Average years of life lost per excess death	16			18
<i>Continuous lifetime exposure^e to 1 mSv (0.1 rem/y)</i>				
70% confidence limits ^d	520	450	70	600
90% confidence limits ^d	410–980	320–830	20–200	300–930
Normal expectation	20,560	19,760	790	17,520
% of normal	2.5	2.3	8.9	3.2
Total years of life lost	8,100			10,500
Average years of life lost per excess death	16			18
<i>Continuous exposure^e to 0.01 Sv (1 rem/y) from age 18 until age 65</i>				
70% confidence limits ^d	2,880	2,480	400	3,070
90% confidence limits ^d	2,150–5,400	1,670–4,500	130–1,160	2,530–4,580
Normal expectation	20,910	20,140	780	17,710
% of normal	14	12	52	18
Total years of life lost	42,200			51,800
Average years of life lost per excess death	15			17

*Based on an equal dose to all organs and the committee's preferred risk models—estimates rounded to nearest 10.
^bSum of respiratory, breast, digestive, and other cancers.
^cEstimates for leukemia contain an implicit dose rate reduction factor.
^dAdditional sources of uncertainty are discussed in Annex 4E.
^eA dose rate reduction factor has not been applied to the risk estimates for solid cancers.

BEIR V

18760_31



TABLE 1-1 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.

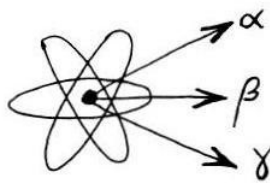
	All solid cancer			
	Males	Females	Males	Females
Excess cases (including non-fatal cases) from exposure to 0.1 Gy	800 (400, 1600)	1300 (690, 2500)	100 (30, 300)	70 (20, 250)
Number of cases in the absence of exposure	45,500	36,900	830	590
Excess deaths from exposure to 0.1 Gy	410 (200, 830)	610 (300,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

BEIR VII

18760_32



RADIOACTIVE EMISSION:



Alpha particle

Beta particle

Gamma ray

37 billion/second = **1 Curie**

18760_33

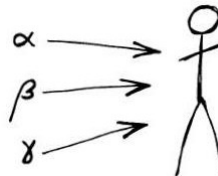


RADIOACTIVE EXPOSURE or DOSE:

Alpha particle

Beta particle

Gamma ray



1 rem = a measure of exposure or dose

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

18760_34



Penetrating power in living tissue:

ALPHA: Less than 1 millimeter

BETA: Several millimeters

GAMMA: Very penetrating

18760_35



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

18760_36