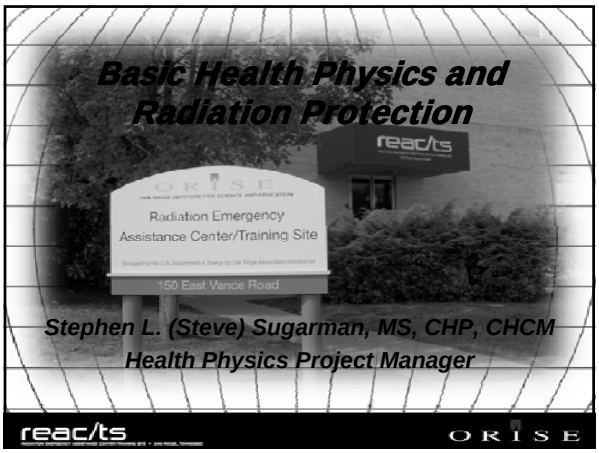


Importance of HP Integration

An understanding of the basic health physics concepts is important because it helps build the foundation for understanding the mechanisms of radiation injury.

Additionally, it is essential that good communications occur between the medical and health physics staffs.

reac/ts ORISE

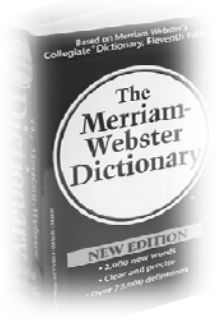
Objectives

The student should be able to:

1. Discuss basic radiation terminology
2. Describe the various types of ionizing radiation
3. Discuss the difference between irradiation and contamination
4. Describe basic ALARA principles

reac/ts ORISE

Common Sense



According to Merriam-Webster, common sense is a sound and prudent judgment based on a simple evaluation of the situation or facts

reac/ts ORISE

Radiation

- According to the Health Physics Journal (HPJ-60) radiation is the emission and propagation of energy through space or through a medium in the form of waves.

reac/ts ORISE

What is Non-ionizing Radiation?

- Some forms of energy can be considered radiation but don't produce ionization
- Examples include radio waves, light, UV radiation and microwaves
- These forms of radiation will not be considered in this discussion of "radiation"

reac/ts ORISE

Discoveries

- The discovery of X-rays (in 1895) was first announced by Roentgen in the public press on January 4, 1896
- While investigating the work of Roentgen, Becquerel discovers radioactivity in 1896
- J.J. Thompson identifies the electron as a particle in 1897.
- 1899: Ernest Rutherford discovers alpha particles and beta particles (he calls them alpha and beta rays...discovers alphas are particles in 1904)
- 1902: Ernest Rutherford and Frederick Soddy publish their theory of radioactive decay (charged particles are emitted resulting in different isotopes)
- 1905 : $E = MC^2$
- The atomic nucleus was discovered in 1911 (Rutherford)
- Niels Bohr publishes his theory of atomic structure in 1913
- Rutherford discovers the proton in 1919
- 1932: Chadwick identifies the neutron

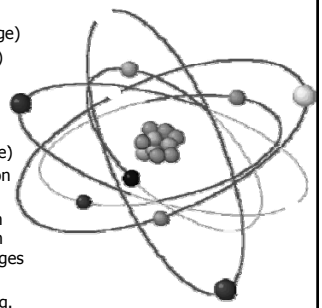
reac/ts ORISE

The Atom and Ionizing Radiation

In the nucleus:

- Protons: Z (positive charge)
- Neutrons: N (zero charge)
- Each about same mass
- Z + N = A

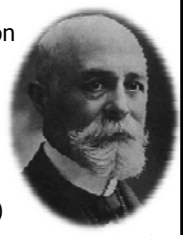
- Outside the nucleus
  - Electrons (negative charge)
  - about 1/2000 of the proton mass
- Ionizing radiation has enough energy to strip electrons from atoms which can create changes within the cell.
- All nuclear radiation is ionizing.



reac/ts ORISE

What are Radioactive Materials?

- Materials that emit ionizing radiation
- Chemically identical to their non-radioactive counterparts
- Behave in the body the same as their non-radioactive counterparts (for example, radioactive iodine behaves the same as stable iodine)



Becquerel

reac/ts ORISE

Effects of Ionization

- Ionizing radiation is extremely easy to detect
- Ionizing radiation may be absorbed by shielding
- Ionization, IF it causes the disruption of a biologically important molecule, CAN lead to biological damage

reac/ts ORISE

Energy Units for Measuring Ionizing Radiation

Radiation energies are typically measured in units of keV (1000 electron volts) or MeV (million electron volts). This is the amount of energy that an emission has available to deposit into tissue.

C-14 beta	157 keV or 0.157 MeV
Cs-137 gamma	662 keV or 0.662 MeV
Am-241 alpha	5.485 MeV

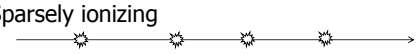
reac/ts ORISE

Linear Energy Transfer

Linear Energy Transfer (LET): how much of a radiation's energy is transferred across a path.

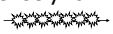
<u>Low LET</u>

- Track average LETs ~0.2 to 3.5 keV/um
- Sparsely ionizing



<u>High LET</u>

- Track average LETs ~10s to 1000 keV/um
- Densely ionizing



reac/ts ORISE

Types of Ionizing Radiation

- Alpha α
- Beta β
- Gamma γ
- X-ray X
- Neutron n

Ernest Rutherford

reac/ts ORISE

Alpha Particles

- 2 protons and 2 neutrons (plus two charge) emitted from heavy elements
- Most have energies between 4-8 MeV
- Very short penetration
  - a few cm in air
  - a few microns in tissue (less than the outer dead cell layer)
- Easily shielded
- High LET, efficient at creating ionization

reac/ts ORISE

Alpha Particles (Hidden Slide)

Radionuclide	Energy (MeV)	Half-Life
U-238	4.2 (75%) 4.15 (25%)	4.51 x 10^9 years
Ra-226	4.78 (95%) 4.60 (5%)	1602 years
Rn-222	5.49	3.82 days
Po-218	6.00	3.05 min
Po-210	5.305	138 days

reac/ts ORISE

Beta Particles

- High energy "electron" emitted from nucleus
- Can have wide range of energies depending upon the particular radionuclide
- Moderately penetrating
  - up to a few meters in air
  - millimeters in tissue
- Not as efficiently ionizing as alpha particles

Beta Particles (Hidden Slide)

Radionuclide	Energy-Max (MeV)	Half-Life
H-3	0.0186	12.3 years
P-32	1.71	14.3 days
Sr-90 Y-90	0.544 2.25	28.1 years 64 hour

Gamma Radiation

- Electromagnetic energy emitted from the nucleus
- Specific energies can be used for identification
- Very penetrating (many meters in air)
- Can be difficult to shield, often shielded with lead

Gamma Rays (Hidden Slide)

Radionuclide	Energy (MeV)	Half-Life
Ir-192	0.468	74 days
Cs-137	0.662	30.0 years
Co-60	1.17 1.33	5.26 years

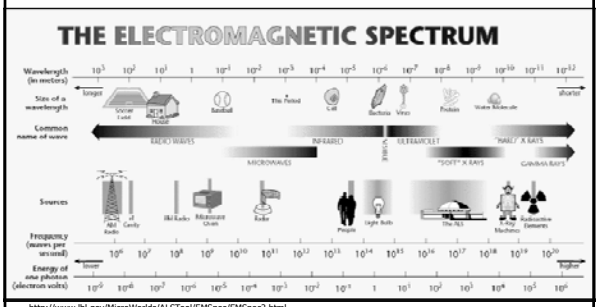
reac/ts ORISE

X-Rays

- Electromagnetic energy emitted from outside the nucleus
- May be "machine-produced" by bombarding high energy electrons on a target causing target electrons to change energy shells.
- May also be emitted from radioactive materials
- Similar shielding and penetrating powers as gamma radiation

reac/ts ORISE

Electromagnetic Waves



http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

reac/ts ORISE

Neutron Radiation

- Neutral particle emitted from the nucleus
- Can be very penetrating
- Requires special consideration for shielding
- Can induce radioactivity when absorbed by stable elements (N, Na, Al, S, Cl, P, etc.)

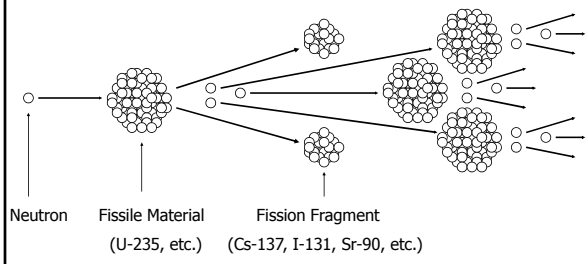
reac/ts ORISE

Basics of Criticality

- Fission - the splitting of the nucleus of the atom - generally into two fission products (atomic masses around 90 and 135) and 2-3 high-energy (fast) neutrons
- Steps of fission
  - nucleus absorbs neutron
  - excited nucleus splits into unequal fragments
  - neutrons (fast) and prompt gammas emitted
- About 200 MeV/fission (around 165 MeV kinetic energy, rest particles/photons/decay energies)

reac/ts ORISE

Nuclear Fission



reac/ts ORISE

Activity and Activity Units

- Activity is the number of disintegrations (or transformations) per time occurring in a radioactive material
- Conventional unit (USA): curie (Ci)
  - 1 Ci = 3.7×10^{10} disintegrations per second
- SI unit: becquerel (Bq)
  - 1 Bq = 1 disintegration per second
- 1 Ci = 3.7×10^{10} Bq

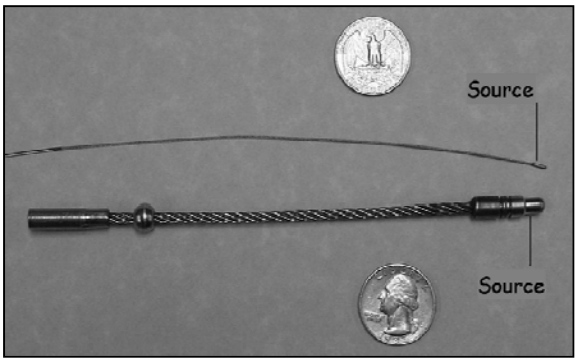
Note: 1 µCi = 2.22 million dpm = 37 kilobecquerels (0.037 MBq)

reac/ts ORISE

Specific Activity

- Defined as activity per unit mass
  - Ci/g, Bq/g, etc.
- Ci/g = $(1.3 \times 10^8)/(T_{1/2}$ in days x A)
- Long $T_{1/2}$ = low SpA; short $T_{1/2}$ = high SpA
- Remember the mass, or amount of matter, is different from the amount of activity present

reac/ts ORISE



reac/ts ORISE

Specific Activities (Hidden Slide)

Radionuclide	Energy (MeV)	Half-Life	Specific Activity (Ci/g)
U-238	4.2 (75%) 4.15 (25%)	4.51×10^{9} yrs	3.33×10^{-7}
Cs-137	0.662	30.0 yrs	87
Co-60	1.17 1.33	5.26 yrs	1.13×10^{3}
H-3	0.0186 max	12.3 yrs	9.64×10^{3}

reac/ts ORISE

Half-Life

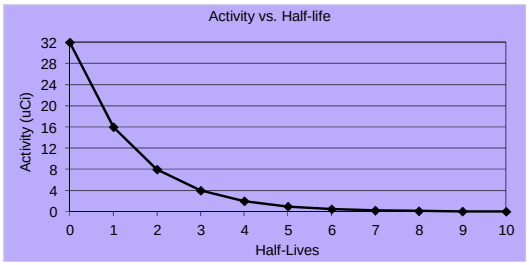
- Time required for a radioactive substance to lose 1/2 of its radioactivity
- Each radionuclide has a unique half-life
- Half-lives range from extremely short (fraction of a second) to billions of years

reac/ts ORISE

Example of the Effect of Half-life

- Assume an initial amount of 32 microcuries of Tc-99m with a half-life of ~6 hours
  - after 1 half-life (6 h): 16 microcuries
  - after 2 half-lives (12 h): 8 microcuries
  - after 3 half-lives (18 h): 4 microcuries
  - after 4 half-lives (24 h): 2 microcuries
- After 10 half-lives, less than 1/1000 of the original activity remains (any isotope!).

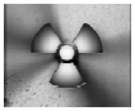
reac/ts ORISE



reac/ts ORISE

Irradiation

- With an Irradiation there is no radioactive material transferred.
- An irradiated patient is NOT radioactive and cannot transfer contamination or radiation to a health care provider.



reac/ts ORISE

Radiation Quantities and Units

Quantity	Measures	Old Units	SI Units
Exposure	Ionization	roentgen (R)	Coulomb/kg
Absorbed Dose	Energy deposition	rad	Gray (Gy)
Dose Equivalent	Biological damage/risk	rem	Sievert (Sv)

Dose rates are given in quantity per time units, such as absorbed dose rate, Gy/hr.
For external exposure to beta, gamma, and X-rays, 1 R = 1 rad = 1 rem.

reac/ts ORISE

What are Quality Factors ?

- The QF relates the amount of biological damage, and resulting risk, caused by any type of radiation to that caused by the same absorbed dose of x- or gamma-rays.
- QF (x, gamma, beta) = 1
- QF (alpha) = 20 (internal only)
- QF (neutron) = 3--20, depending on energy

reac/ts ORISE

What is Exposure?

- In physics, "exposure" relates to the amount of ionization produced by x- or gamma rays in air under standard conditions (Roentgen or Coulombs/kg)
- Colloquially, "exposure" means being in the presence of ionizing radiation; one is "exposed" to radiation as one may be "exposed" to heat, cold, or the measles.

reac/ts ORISE

What is Radiation Dose?

- Dose refers to the absorption of radiation energy per unit mass of absorber.
- The conventional (USA) dose unit is the rad: 1 rad = 100 ergs per gram
- The SI unit is the Gray (Gy): 1 Gy = 1 Joule per kilogram
- 1 Gy = 100 rad

reac/ts ORISE

An easy way to remember that the rad is the US unit of absorbed dose is:

***R**adiation*

***A**bsorbed*

***D**ose*

reac/ts ORISE

What is Dose Equivalent?

- Dose equivalent refers to the biological damage, and resulting risk, from a radiation dose
- Dose equivalent = Dose x Quality Factor
- The conventional (USA) unit of dose equivalent is the rem
- The SI unit is the Sievert (Sv)
- 1 Sv = 100 rem

reac/ts ORISE

An easy way to remember that the rem is the US unit of dose equivalent is:

***R**ad*

***E**quivalent*

***M**an*

reac/ts ORISE

ALARA

ALARA ("As Low As Reasonably Achievable") means making every reasonable effort to maintain exposures to ionizing radiation as far below the regulatory dose limits as practical, taking into account economic, societal, and other relevant considerations.

reac/ts ORISE

Reduction of External Dose

- Minimize the time spent near the radiation source
- Maximize the distance away from the source ($1/R^2$)
- Make use of available shielding
- Minimize the quantity of radioactive materials handled

reac/ts ORISE

What is Contamination?

- Contamination is simply the presence of radioactive material where it is not wanted
- Persons may be contaminated either externally, internally, or both
- Exposure does not necessarily imply contamination

reac/ts ORISE

Internal Deposition

- Annual Limit on Intake (ALI)
  - The amount if a radionuclide that, if taken into the body, will result in a regulatory limit being met.
- The ALI can be used to determine the magnitude of a contaminating event.
- ALI and DAC tables can be found in Federal Guidance Report #11 (EPA)

reac/ts ORISE

ALIs of Interest and Conversions

Emission	Assumed Nuclide	Inh. ALI (µCi)	dpm	Ing. ALI (µCi)	f_1 value	dpm*
alpha	Am-241	0.006 - W	1.3×10^4	0.8 - W	0.0001	1.8×10^2
beta	Sr-90	4 - Y	8.9×10^6	30 - D	0.3	2.0×10^7
gamma	Cs-137	200 - D	4.4×10^8	100 - D	1.0	2.2×10^8

Nuclide	Inh. ALI (µCi)	dpm	Ing. ALI (µCi)	f_1 value	dpm*
H-3	80,000 (H_20 Vapor)	1.8×10^{11}	80,000 (H_20 Vapor)	1.0	1.8×10^{11}
Co-60	30 - Y	6.7×10^7	200 - Y	0.3	1.3×10^8
U-235, 238	0.04 - Y	8.9×10^4	10 - D	0.05	1.1×10^6
Pu-238	0.007 - W	1.6×10^4	0.9 - W	0.001	2.0×10^3
Pu-239	0.006 - W	1.3×10^4	0.8 - W	0.001	1.8×10^3
Cf-252	0.02 - W	4.4×10^4	2.0 - W	0.001	4.4×10^3

Most restrictive ALI values in FGR-11 are listed (solubility class also listed).
* (Ing. ALI)(f_1) = dpm to bloodstream due to ingestion (not necessarily most restrictive)

reac/ts ORISE

Reduction of Internal Dose

- Minimize and control contamination
- Properly use protective clothing
- Do not eat, drink, or smoke in contamination areas
- Check yourself for contamination prior to leaving a potentially contaminated area

reac/ts ORISE

Annual Regulatory Limits

	rem	Sv
Members of the public	0.100	0.001
Occupational limits		
Total effective dose equivalent	5	0.05
Single organ dose equivalent	50	0.5
Lens of the eye	15	0.15
Skin dose equivalent	50	0.5
Extremity dose equivalent	50	0.5
Fetal dose (declared pregnancy)	0.5	.005

reac/ts ORISE

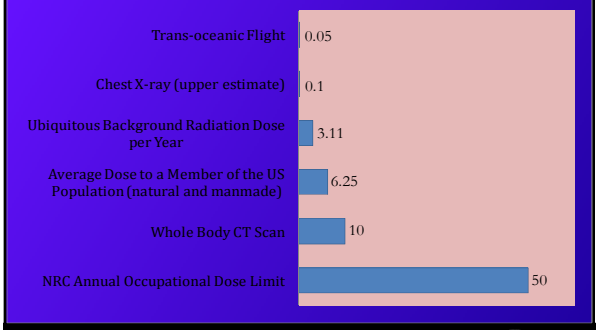
Examples of Radioactive Materials

Nuclide	Half Life	Specific Activity (Ci/g)	Emits	Use
H-3	12.3 y	9640	β	Luminous signs
Co-60	5.3 y	1130	β, γ	Medical therapy
I-131	8.05 d	1.23×10^5	β, γ	Medical therapy
Cs-137	30 y	87	β, γ	Medical therapy
Ir-192	74 d	9170	β, γ	Ind. radiography
Ra-226	1,620 y	0.99	α	Medical therapy
U-235	7×10^8 y	2.1×10^{-6}	α	Reactors/weapons
Pu-238	87 y	17.2	α	RTG's
Pu-239	24,400 y	0.061	α	Reactors/weapons
Pu-241	13.2 y	112	β	Waste product
Am-241	458 y	3.2	α, γ	Smoke detectors

reac/ts ORISE

Copyright 2011, ORAU

Dose Comparisons (in mSv) [x 100 for mrem]

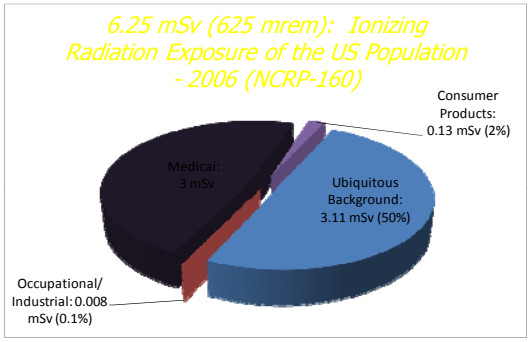


reac/ts ORISE

Typical Radiation Exposures

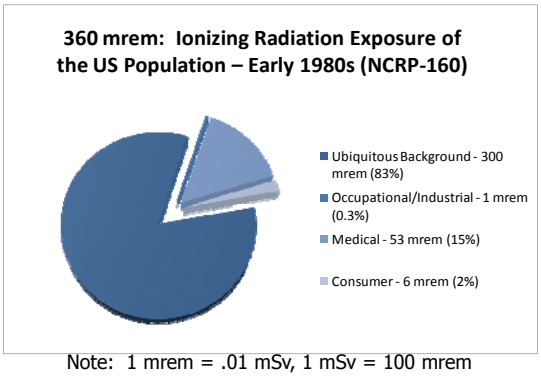
Natural background and manmade radiation (annual average dose equivalent, inc. radon)	6.25 mSv / 625 mrem
Diagnostic chest x-ray	0.1 mSv / 10mrem
Flight from LA to Paris	0.048 mSv / 4.8 mrem
Backscatter Scan (airport)	5-10 µrem
Barium study	8 mSv / 800 mrem
Smoking 1.5 packs per day - 1 year dose	0.16 Sv / 16 rem

reac/ts ORISE



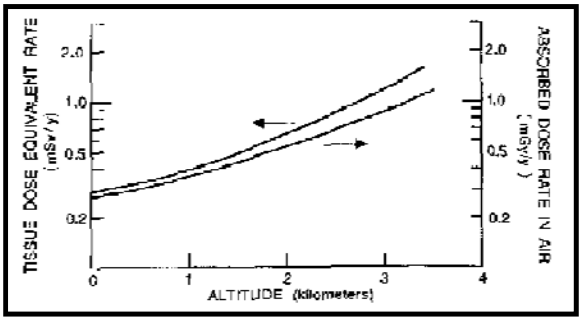
Note: 1 mrem = .01 mSv, 1 mSv = 100 mrem

reac/ts ORISE



Note: 1 mrem = .01 mSv, 1 mSv = 100 mrem

reac/ts ORISE



reac/ts ORISE

Review

- What are the types of ionizing radiation?
- What units are used for activity?
- What are the units of dose? Dose equivalent?
- How do you get contaminated?
- How do you get irradiated?
- How can you limit your dose?

reac/ts ORISE

The Medical Aspects of Radiation Incidents

Topics covered include:

- Basic health physics
- Basic external/internal dose calculation
- Acute local and whole body injuries/illnesses
- Treatment for internal contamination
- Patient decontamination
- Delayed effects
- Psychological aspects

http://orise.orau.gov/files/reacts/medical-aspects-of-radiation-incidents.pdf

reac/ts ORISE

U.S. scraps plan for anti-radiation pills

By Mimi Hall, USA TODAY Updated 1/29/2008 10:30 AM

WASHINGTON — The federal government will not give anti-radiation pills to millions of people who live 10 to 20 miles from a nuclear plant because there are more effective ways to protect people in case of an accident or terrorist attack, the White House said Monday.

(Name Deleted) holds a pack of potassium iodide tablets in 2002. (Name Deleted) bought anti-radiation pills for his family and employees in case of a radiation emergency. The president's top science adviser concluded Monday that there are more effective ways of protecting Americans during a nuclear crisis.

reac/ts ORISE

White House May Halt Anti-Radiation Pills The Skinny: Plan Born Of Terror Fears Scrapped To Boost Confidence In Nuclear Power

CBS News.com
New York,
Oct. 23, 2007
By Keach Hagey

Is the White House admitting that global warming is scarier than terrorism?

That seems to be the message behind USA Today's report that the Bush administration may scrap a plan to give anti-radiation pills to millions of people, five years after Congress ordered that the tablets be made available to anyone living within 20 miles of a nuclear reactor.

reac/ts ORISE

The New York Times

Anti-radiation Pills Are Urged for Children

Published: Tuesday, April 8, 2003

- Households, schools and child-care centers near nuclear power plants should keep potassium iodide pills on hand to protect children from thyroid cancer in the event of a release of radiation, the American Academy of Pediatrics has recommended.
- Children are especially vulnerable to the effects of radiation, in part because they are closer to the ground, where fallout settles and because their bodies absorb and metabolize substances differently, the pediatrics academy said.

reac/ts ORISE

QUESTIONS????

Remember, medical care takes priority over contamination concerns.

Presentation created by Steve Sugarman, MS, CHP