CEMP TRAINING SESSION 15-17 JULY 2013

RADIOACTIVITY & RADIATION CHARACTERISTICS

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2013 Training Session

Occupational Dose Equivalent Limits

- General Public

  100 mrem/yr

- Any Occupational Worker (unmonitored)

  100 mrem/yr

- Radiation Worker (monitored)

  5,000 mrem/yr = 5 rem/yr

Man-Made Sources

- Medical radiation ~ 48%
- Nuclear weapon tests < 0.1%
- Consumer products ~ 2%
- All energy production & research < 0.1% or < 0.5 mrem
- Industrial uses < 0.1%
- Fukushima: Dose ~ 1 ft elevation

Medical Radiation

- X-rays - medical (CT's, etc.) & dental
- Radioactive material for diagnosis
  ^{131}I, ^{99}Tc, ^{32}P, ^{3}H, ^{14}C
- Radioactive material for therapy
  ^{60}Co, ^{137}Cs, ^{226}Ra, neutrons
- Annual dose ~298 mrem ~48% total

EPA annual US (LNT) risk from cancer

1.16 E-3 cancer-inductions/person-rem
5.8 E-4 cancer-deaths/person-rem

US population 330 million in 2006 and medical = 0.3 rem
= 115,000 induced cancers from medical
= 57,000 cancer deaths from medical
Medical radiation increased since 2006 so cancer risks greater

Industrial nuclear < 0.1% total 620 mrem radiation exposure
Industrial radiation including all nuclear related activities
= 230 induced cancers
= 120 cancer deaths

ALARA

- As Low As Reasonably Achievable
  (called ALARA by regulators)

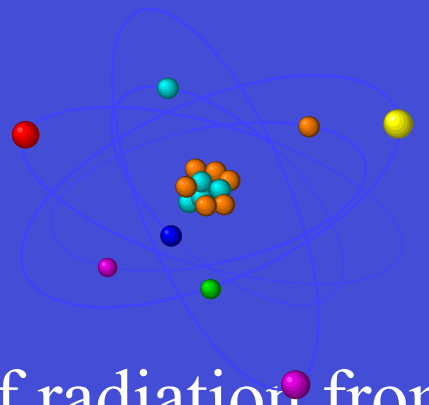
Radiation protection program manage exposures (individual & collective to workforce & public) as low as social, technical, economic, practical, public policy permit

ALARA not dose limit but a process
"maintain dose levels"
As Low As Reasonably Achievable

Radium Effects Confirmed

- 1925
- Suspicions develop around watch dial painters' jaw lesions
- Dentists diagnose lesions as jaw necrosis due to radium deposits in jaw bone
- Doctor notes bone changes and anemia in dial painters

What is Radiation?



Radiation: energy in motion

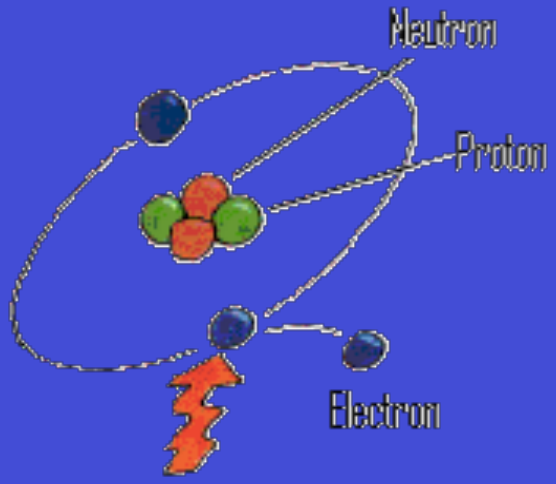
Radioactivity: spontaneous emission of radiation from nucleus of an unstable atom

Isotope: atoms with same number of protons, but different number of neutrons

Radioisotope: unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation.

About 5,000 natural and artificial radioisotopes identified

Types of Radiation



- **Non-Ionizing Radiation**: Radiation that does not have sufficient energy to dislodge orbital electrons.

Examples of non-ionizing radiation: microwaves, ultraviolet light, lasers, radio waves, infrared light, and radar.

- **Ionizing Radiation**: Radiation that has sufficient energy to dislodge orbital electrons.

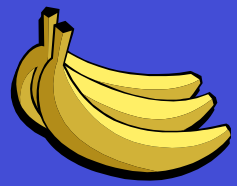
Examples of ionizing radiation: alpha particles, beta particles, neutrons, gamma rays, and x-rays.

Terrestrial Radiation

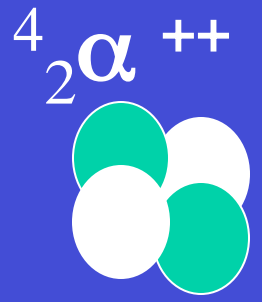
Terrestrial radiation emitted from *Primordial radio nuclides* –

Radio nuclides left over when earth was created.

- Common radionuclides deposited during formation of earth:
  - –Radioactive Potassium (K-40) found in bananas, in human body, plant fertilizer and where potassium exists.
  - –Radioactive Rubidium (Rb-87) is found in brazil nuts among other things.
  - –Radioactive Carbon (C-14) produced in upper atmosphere from cosmic radiation



Terrestrial Radiation

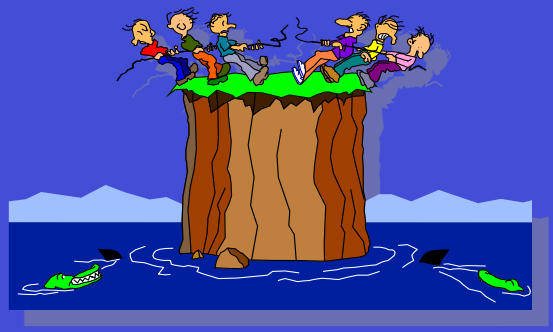


- Greatest contributor is ^{226}Ra (Radium) with significant levels also from ^{238}U, ^{232}Th, and ^{40}K.
  - Igneous rock contains highest concentration followed by sedimentary, sandstone and limestone.
  - Fly ash from coal burning plants contains more radiation than that of nuclear or oil-fired plants.

Compare Backgrounds

- Sea level - 30 mrem/year

  from cosmic radiation



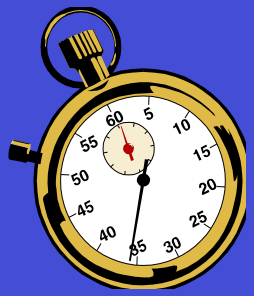
- 10,000 ft. altitude - 140 mrem/year

  from cosmic radiation

- 30,000 ft. altitude - 10 mrem/hr

  Aircraft flight from cosmic radiation

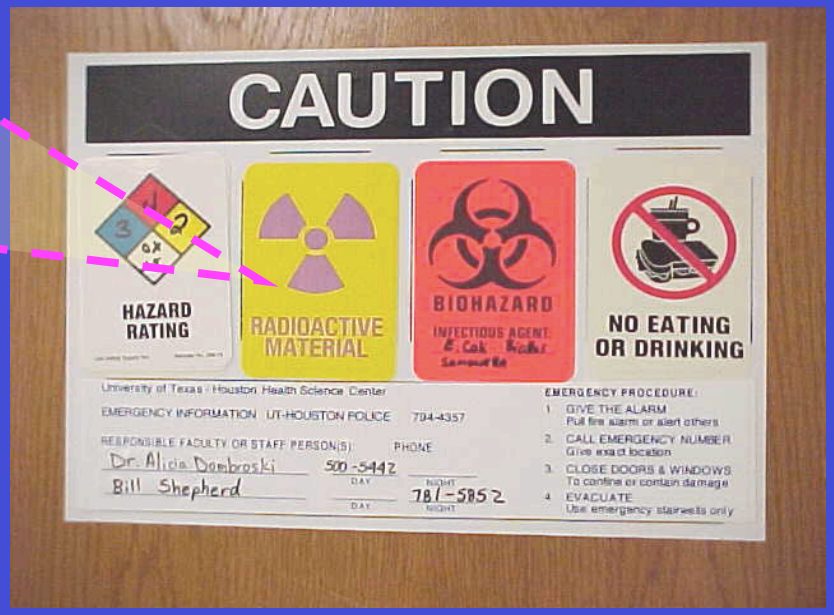
Consumer Products and Radioactive Material



Many sources of radiation in consumer products

- Smoke detectors
- agricultural products - fertilizer
- long lasting light bulbs
- building materials (sheet rock)
- static eliminators in manufacturing
- luminous dials of watches
- clocks and compasses
- etc.

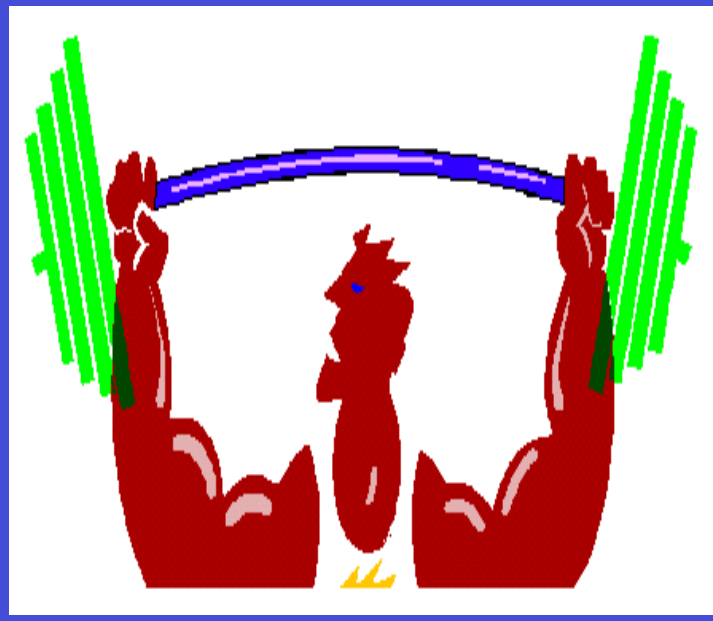
Radiation Postings



- Radiation labeled on door, work area & storage area
- Research laboratories work with radioactive materials
- Contamination warning for work in lab with radioactive materials
- Wear gloves, safety glasses, protective clothing, not eating or smoking

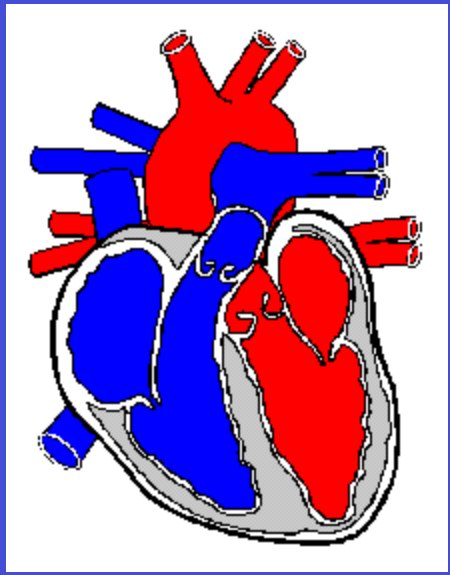
Radioactivity Units

- Rate of Disentegration or Decay "Strength"
- Curie (Ci) about 1 gram of radium
- 3.7 X 10^{10} disintegrations/sec
- Becquerel (Bq) = 1 (dps)
- 1 mCi = 37 MBq



Dose Equivalent

- Scale for equating relative hazards of various types of ionization in terms of equivalent risk
- Damage in tissue measured in rem
  - (Roentgen Equivalent Man)
- Q:risk of biological injury
- rem = Q * rad
- Sievert (Sv)
- 1 Sv = 100 rem



What do we really need to know?

- 1 R ≈ 1 rad = 1 rem

  For gammas & betas

- 1 rad ≠ 1 rem

  For alphas, neutrons & protons

  1 rem = 1 rad * Q

Annual Radiation Exposure Limits

Occupationally Exposed Worker:

	rem	mrem
Whole body	5	5000
Eye	15	15,000
Shallow	50	50,000
Minor	0.5	500
Pregnant Worker	0.5*	500*

*9 months

General Public: 100 mrem/year or 2mrem/hour

Ensuring Compliance to Radiation Exposure Limits

- Use established activity limit for each isotope
- Compare with similar situations
- Estimate with meter
- Calculate
  - Time, Distance, Shielding, Type, Energy, Geometry
- Measure
  - TLD Chip, Luxel
  - Bioassay

Who should wear radiation dosimeters or badges?

- Those “likely” to exceed 10% of their annual limit are required
- Those who would like a badge
- Minors & Declared Pregnant Workers*

- Industrial use of nuclear materials < 0.1% radiation exposure to public and workers.
- Environmental Protection Agency asserts annual US radiation risk from cancer
  - 1.16 E-3 cancer-inductions/person-rem
  - 5.8 E-4 cancer-deaths/person-rem
- US population is 330 million so for 2006
  - Annual cancer induction from medical
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Perspective of Risk

Estimated Loss of Life Expectancy during lifetime

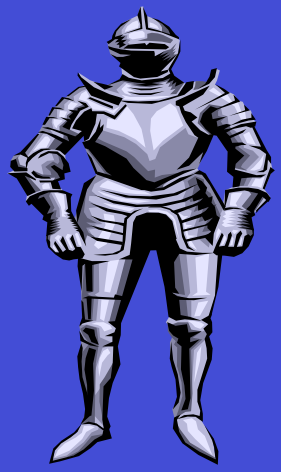
Health Risks	
20 cigarettes/day	6 years
15% overweight	2 years
Consuming alcohol	1 year
All Accidents	1 year
Motor vehicle	207 days
Home accident	74 days
Drowning	24 days
Natural hazards	7 days
Medical radiation	15 days
620 mrem/y for 47 y (US Background dose)	31 days
1 rem/y for 47 y	50 days

Industrial Accidents	
All industries	60 days
Agriculture	320 days
Construction	227 days
Mining	167 days
Transportation	160 days
Government	60 days
Manufacturing	40 days
Trade	27 days
Services	27 days
Nuclear Plant	27 days

Declared Pregnant Worker (Embryo / Fetus)

- Policy: Female radiation worker encouraged to voluntarily notify supervisor (written) if pregnant
- Employer must provide agreeable work with limited (~no rad) exposure & no loss of pay or promotional opportunity
- Further occupational rad exposure unlikely during pregnancy

External & Internal Radiation Dose Reduction



- Use shielding if possible
- Minimize time in radiation field
- Maximize distance to rad source
- Dose ~ Source x time / $(\text{distance})^2$

Radiological Control Responsibilities

- Provide technical & programmatic control over radiation & radioactive materials
- Provide Health Physics (HP) personnel & monitoring equipment
- Issue Radiation Work Permits (RWPs)
- Maintain dosimetry program
- Maintain training program

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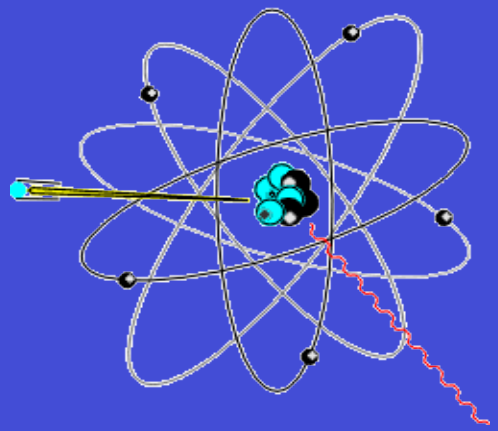
Radiological Areas

- Radiological Buffer Area
- Radiation Area
- High Radiation Area
- Very High Radiation Area
- Contamination Area
- High Contamination Area
- Fixed Contamination Area
- Soil Contamination Area
- Airborne Radioactivity Area

Contamination Area



Area where surface has removable contamination > given limits

Entry Requirements:

Radiological Training II

Worker signs RWP

Requirements for work in area:

Personnel dosimeter if necessary

Minimize dust generation

Respiratory protection if necessary

Soil Contamination Area

Area where surface soil contaminated above limits

<u>Entry Requirements</u>:
Radiological Training II
Worker signs RWP

<u>Requirements for work in area</u>:
Personnel dosimeter if necessary
Minimize dust generation
Minimize earth disturbance
Respiratory protection if necessary

Radioactive Material Area

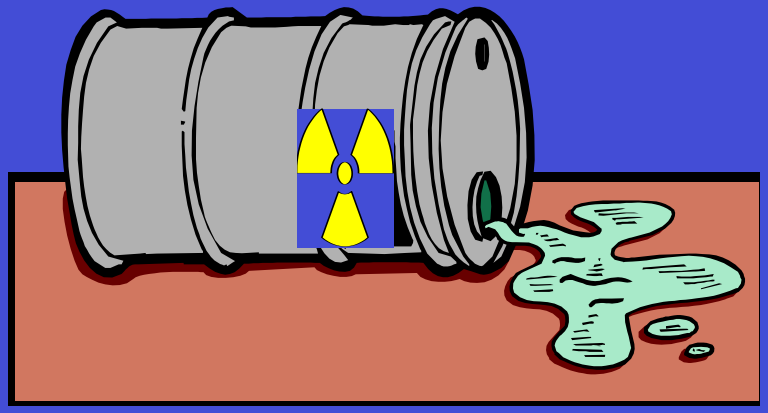
Entry requirements into Rad Materials Area if whole body dose rate > 5 mrem/hour or contamination > specified limits

Same for entry into Radiation Area or Contamination Area

Depends on radiological hazard present

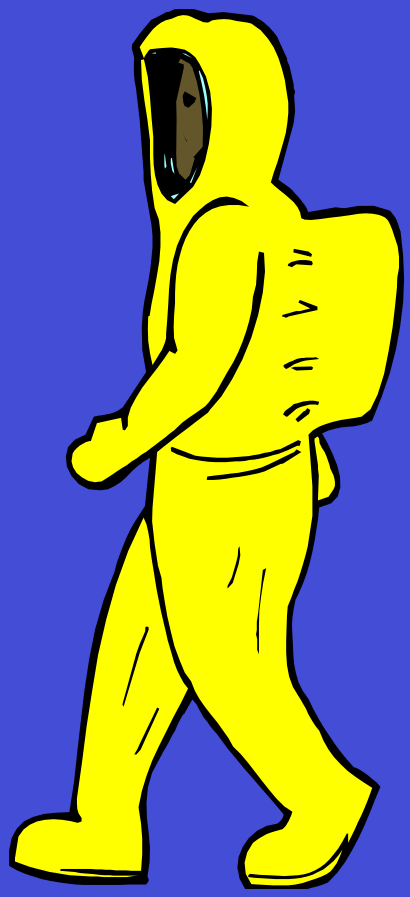
Control of Radioactive Spills

- **Stop or secure spill source**
- **Warn others in area**
- **Isolate spill if possible**
- **Minimize exposure & contamination**
- **Secure unfiltered ventilation**
- **Requirements for exiting**
  - **- Site specific monitoring**
  - **- Monitor per posted instructions before entry to clean area**
- Notify Rad Control personnel
- Changing rad conditions.
- Actions don't create rad problems for others.
- Be alert for activities that change rad conditions



Personnel Protective Clothing

- Protective Clothing used to enter areas with rad levels above specified limits to prevent skin contamination
- Clothing depends on work area, rad conditions, job, etc.
- Full protective clothing includes
  - coveralls
  - cotton glove liners & gloves
  - hood
  - shoe covers & rubber overshoes



Radiation Damage

- **Direct Effects:**
  - Ionization can break chemical bonds
- **Indirect Effects:**
  - Ionized water results in radicals H^+ or HO^- or H_2O_2
  - These radicals cause chemical damage
- **Location of damage important:**

  Cell Nucleus or Cytoplasm

Possible Effects on Cells

- No damage evident
- Damage repaired & cell normal
- Damage not repaired & cell functions abnormally
- Cell dies

Cell Sensitivity

- Cells have different rad sensitivity
- Most sensitive: Cells actively dividing (e.g., stem & blood cells)
- Moderate sensitive: Less specialized cells
- Least sensitive: Specialized cells or less actively dividing (nerve, brain, bone, muscle cells, skin)

Factors for Biological Damage

- Total dose (how much)
- Dose rate (how fast)
- Type of radiation
  (alpha, beta, gamma, neutron)
- Area exposed
  (total body, internal, hands, etc.)
- Cell sensitivity
- Individual person sensitivity

Risk From Exposure

- No observed increase of risk at occupational exposures
- Risk factor: 4×10^{-4} latent health effects per rem (LNT model)
- Cancer formation latency time > 10 yr
- More solid tumor formation old age

US radiation setting bodies constrained

- No deliberate exposure to radiation justified unless some benefit
- All radiation exposure must be kept "As Low As Reasonably Achievable" ALARA
- Radiation doses to individuals should not exceed mass maximum permissible doses - MPD's.

No evidence for harm at low levels of radiation

But following assumptions made

- linear non threshold dose relationship LNT applies for any radiation exposure (>0)
- no threshold for radiation doses below which no health effects occur
- No biological recovery from radiation effects at any dose level

Risk of worker death from radiation only from

CANCER

- No observable workers injuries for exposures at regulatory levels
- Regulatory dose limits far below threshold for observable stochastic effects