Physical Agents in Environmental and Occupational Health

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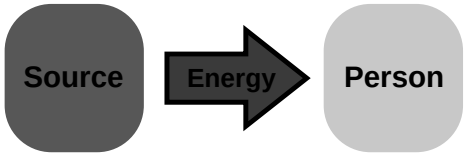
Model for Physical Agents



Type and quantity of energy affect health risk

Some Types

- Radiation
  - ✓ Ionizing
  - ✓ Nonionizing
- Noise
- Thermal: Heat and Cold
- Vibration
- Plus
  - ✓ Electricity
  - ✓ Impact and Shock Waves
  - ✓ Pressure (Diving and Altitude)

Quantity

- Total Amount of Energy Absorbed (Work)
  - ✓ What does it take to raise water temperature?
  - ✓ Joules
- Rate of Absorption (Power)
  - ✓ How fast does the temperature rise?
  - ✓ Watts (J/s)
- Normalized to Surface Area (W/m^2, mW/cm^2)
- Frame of Reference
  - ✓ Basal Metabolic Rate is 6 mW/cm^2

Bernard Watt-O-Meter

The BWOM does not exist in this reality; it may violate known physical laws and grossly simplifies others.

But perhaps it will give you some perspective.

If you care to know how I came up with a number, ask.

Ionizing Radiation

Q1

Who discovered X-rays? Hint: First example was radiograph of wife's hand.

a. Becquerel
b. Curie
c. Roentgen
d. Seivert
e. Zen

Q2

What disease is most associated with low-level exposures to ionizing radiation? Hint: By 1940s, incidence among physicians, especially radiologists, was higher than general population.

a. leukemia
b. lung cancer
c. schizophrenia
d. tuberculosis
e. xeroderma pigmentosum

Q3

Among consumer products, what is the greatest source of ionizing radiation exposure?

a. Cigarettes
b. Gas stoves
c. Old luminous watch dials (pre-60s)
d. Smoke detectors
e. Televisions

What happened 113 years ago?

In October 1895, Wilhelm Roentgen Discovered X-rays

Packets of Energy Called Photons

- ✓ε = 12 eV to 10^8 eV
- ✓Can Ionize Atoms

1845-1923

Results of Ionization

Break DNA -- Direct Hit

Create Free Radicals and Peroxide

Results on Cell Viability

- ✓No Effect
- ✓Cell Dies
- ✓Takes a Step on Carcinogenic Pathway

Biological Effects

Determinants of Biological Effects

- ✓ Rate of absorption
- ✓ Total dose
- ✓ Tissue exposed
- ✓ Individual variations

Classes of Effects

- ✓ Acute somatic effects (acute radiation sickness)
- ✓ Delayed somatic effects (leukemia, cancers)
- ✓ Genetic effects (birth defects)

Energy Levels

LD_{50} = 0.3 mW/cm^2

One Time = 0.01 mW/cm^2

Occupational = 0.00000003 mW/cm^2 over 1 yr

Public = 0.0000000008 mW/cm^2 over 1 yr

70 kg person; gamma / x-ray only

Types

Electromagnetic Radiation / Photons
- ✓X-rays
- ✓Gamma Rays

Particle Radiation
- ✓Alpha
- ✓Beta
- ✓Neutron

Chemical Elements

Element
- ✓Defined by Atomic Number
- ✓Atomic Number Equals Number of Protons

Isotopes
- ✓Same Element
- ✓Different Numbers of Neutrons

$_1H^1$ $_1H^2$ $_1H^3$ $_6C^{12}$ $_6C^{14}$

Nuclear Radiation

Nature Seeks Stability

Radioisotopes
- ✓Instability occurs when the right blend is not present
- ✓Nature attempts to create the right blend by radioactive decay.

Nuclear Radiation is Result

Types of Nuclear Radiation

Alpha Particles
- ✓Helium nucleus (2 protons + 2 neutrons)
- ✓Positive charge (+2)
- ✓Dissipate energy quickly
- ✓Travel short distances
- ✓Stopped by sheet of paper / skin

{ $_2He^{4+2}$ }

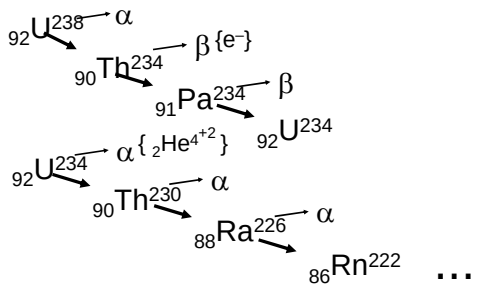
Types of Nuclear Radiation

Alpha Particles

{e^-}

Beta Particles
- ✓Electron (neutron to proton)
- ✓Negative charge (-1)
- ✓Loss energy over short distance
- ✓Stopped by aluminum foil / skin (deeper)

Decay Series



Types of Nuclear Radiation

Alpha Particles
Beta Particles

Gamma Rays
- ✓Excess energy dissipation from nucleus
- ✓Photons with high energy
- ✓Travel great distances
- ✓Give up energy slowly
- ✓Stopped by lead, concrete

Q4

What distinguishes the energy paths associated with alpha and gamma radiation?

a. Gamma radiation is readily stopped.

b. Alpha radiation passes through lead more easily than gamma radiation.

c. An alpha radiation source is a problem only when it is in the body while a gamma source can be a problem inside or outside.

Measurement Units

Activity (Ci / Beq)

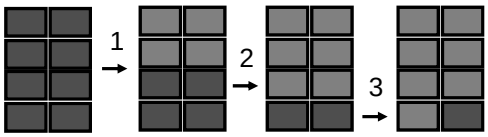
Radiation Absorbed Dose (rad / Gray)

rad Equivalent - Man (rem / Sievert)
- ✓Relative Biological Effectiveness (RBE)
- ✓Gamma has least effect (RBE = 1)
- ✓Alpha has greatest effect (RBE = 20)
- ✓Beta tends to be closer to Gamma (RBE = 1 to 5)

rem = RBE x rad **Sv = RBE x Gr**

Half-Life

Time to reduce activity by 1/2



4 half-lives is a 95% reduction.

Short half-life is related to high activity.

Q5

For the same amount of potential damage (risk) to a particular organ,

A. alpha particles cannot cause any problems, but beta particles can.

B. the amount of energy deposited in the organ is the same, no matter what the type of radiation is.

C. gamma rays require more total energy than alpha particles.

Radiation Threat

Sources
- ✓Natural
- ✓Artificial

Hazards
- ✓External (long distances)
  - Gamma rays
  - X-rays
- ✓Internal (short distances)
  - Alpha
  - Beta

Radon
Major Natural Source

Uranium-238 → (solids) → α → **Radon-222** (gas) → (solids) → **Lead-206**

55%

α and β Particles: Internal Hazard
- Lungs: inhaled
- Stomach and intestines: ingested

Other Natural Sources

Internal: 11%

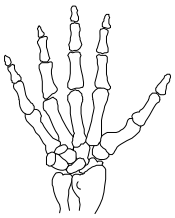
Cosmic: 8%

Terrestrial: 8%

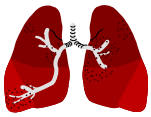
27%

Humans may enhance exposure to natural sources.

Medical X-rays and Nuclear Medicine
Artificial Sources



15%



Other Artificial Sources

Consumer Products: 3%

Occupational: 0.3%

Nuclear Fuel Cycle: 0.1%

3.4%

Commercial Power Generation

Nuclear Fuel Cycle: 0.1%
- ✓Mining and Milling
- ✓Enrichment and Fuel Fabrication
  - Japan Incident
- ✓Power Generation
  - Routine and Catastrophic Releases
  - Three Mile Island
  - Chernobyl
- ✓Waste Disposal

Waste Disposal

High-Level Wastes
- ✓ Nuclear Waste Policy Act (1982)
  - Federal Responsibility
  - Permanent: Yucca Mountain (Open in 20??)
  - Temporary: Monitored Retrievable Storage
- ✓ Military (weapons) Waste: New Mexico

Low-Level Wastes
- ✓ Low-Level Waste Policy Act (1980)
  - State Responsibility
  - Groups of States form Compacts
- ✓ Siting Problems

Q6

What is the role of public health professionals in trying to influence individual decisions concerning ionizing radiation?

A. Ignore it

B. Prudent avoidance

C. As low as reasonably achievable (ALARA)

D. Education on risks and actions

Questions?