HPS 102/RAD 102
Module 4

X. Radiation Quantities and Protection Standards

A. Roles of Responsible Parties

International Commission on Radiological Protection (ICRP) - international team of scientists which makes recommendations on protecting humans, including radiation workers, to the potentially harmful effects of ionizing radiation, including setting annual limits, determining internal doses from ingestion or inhalation, etc.

International Commission on Radiological Units and Measurements (ICRU) - international team of scientists which makes recommendations on radiation quantities and units, suitable measuring procedures, and numerical values associated with radiation protection.

National Council on Radiation Protection and Measurements (NCRP) - sister organization of the ICRP in the United States.

Nuclear Regulatory Commission (NRC) - responsible for promulgating and enforcing laws (Chapter 10, Part 20 of the Code of Federal Regulations - 10CFR20) involving the safe receipt, use, and disposal of radioactive materials.

Agreement States - states which have assumed the authority from the NRC to enforce the safe receipt, use, and disposal of radioactive materials within their own state's jurisdiction. Nevada is an Agreement State. Nevada's law on radioactive materials is found in Nevada Authorization Code 459 - NAC 459.

U.S. Department of Energy (DOE) - responsible for the safe receipt, use, and disposal of radioactive materials within the DOE Complex.

B. Definition of Radiation Quantities

Absorbed Dose (D) - is mean energy imparted by ionizing radiation per mass of interest. The SI Units of absorbed dose are Joules/kg, or J/kg. The special name for the unit of absorbed dose is the Gray (Gy).

1 Gy = 1 J/kg

The old unit of absorbed dose is the rad.

1 rad = 10^{-2} J/kg = 10^{-2} Gy

Absorbed dose gives information on how much energy is being deposited in tissue, but it gives no information on how the energy is being deposited. For example, alphas will

deliver their energy in a much more concentrated way than a beta will. Therefore, absorbed dose must be modified to account for the differences in particles in the way they deposit their energy. This modifying factor is called the **Quality Factor (Q).**

X and gamma rays, Q = 1
Betas, Q = 1
Neutrons of unknown energy, Q = 10
Alphas, Q = 20

Dose Equivalent (H) - the product of D and Q, where D is the absorbed dose at a point of interest in tissue, and Q is the quality factor:

$H = DQ$

The SI Units for H are J/kg. The special name for the unit of dose equivalent is the Sievert (Sv).

1 Sv = 1 J/kg

The old unit for dose equivalent is the rem.

1 rem = 10^{-2} J/kg

The occupational dose limits set forth in both 10CFR20 and NAC 459 for radiation workers are expressed in rem:

Whole body - 5 rem/yr
Any individual organ - 50 rem/yr
Skin - 50 rem/yr
Lens of the eye - 15 rem/yr
Occupational minors - 10% of the annual dose limits for adult workers

Members of the general public - 0.1 rem

Additional definitions:

Deep-dose equivalent (H_d) - applies to external whole body exposure, is the dose equivalent at a tissue depth of 1 cm.

Shallow-dose equivalent (H_s) - applies to external exposure of the skin or extremity, is taken as the dose equivalent at a tissue depth of 0.007 cm averaged over an are of 1 cm^2.

Committed effective dose equivalent ($H_{E,50}$) - a summing of the products of the tissue weighting factors and dose equivalents to those organs or tissues from an intake of radioactive material by an individual during the 50-y period following the intake.

Total effective dose equivalent (TEDE) - the sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal expsoures).

Note that the 5 rem/yr whole body limit is a TEDE. The individual organ limit of 50 rem/yr is a combination of the deep-dose equivalent (external) and the committed dose equivalent (internal) to that organ. The 50 rem/yr limit to the skin is a shallow-dose equivalent limit.

Exposure - the quotient of dQ by dm where dQ is the absolute value of the total electrical charge of all the ions of one sign produced in air when all the electrons (negatrons and positrons), liberated by photons in air of mass dm are completely stopped in air.

$X = dQ/dm$

Where dQ is the sum of the + or - charges produced from secondary electrons "born" in dm. The SI Units of exposure are coulomb/kilogram or C/kg. The old unit of exposure is the Roentgen (R). $1\ R = 2.58 \times 10^{-4}$ C/kg.

Notes:

1. exposure is defined for photons only
2. exposure is defined for air only
3. the interaction between the radiation field and the air is principally by photoelectric effect, Compton effect, and production leading to secondary electrons being liberated
4. does not include Bremsstrahlung interactions
5. present techniques make it difficult to measure exposure when photon energies are above a few MeV or below a few keV.

Relationship between dose and exposure

1R of exposure in air = 0.869 rads in air
1R of exposure = 0.97 rads in tissue