

Quiz-2 on Radiation Dosimetry – External Exposure (April 16, 2001)

Problem 1 (30 points): Briefly explain the following terms:

- a. roentgen: "exposure quantity of  $\gamma$ - and x-radiation which produces ion pairs which are equivalent to 1 esu per  $\text{cm}^3$  of STP air" (conventional unit)
- b. absorbed dose: "**Absorbed dose ( $D$ )**" is defined as the energy absorbed per unit mass of absorber medium due to radiation exposure. Hence, the absorbed dose can be used for any materials including the human body.
- c. dose equivalent: "**Dose equivalent ( $H$ )**" is the absorbed dose modified by the biological effectiveness to human due to radiation type and other modifying factors.
- d. dose commitment: absorbed dose accumulated by the organ until the introduced activity is completely eliminated from the organ
- e. TEDE total effective dose equivalent (TEDE) deep-dose equivalent (for external exposures) + committed effective dose equivalent (for internal exposures)
- f. committed dose equivalent: dose equivalent to target tissue T accumulated over 50 years following the intake of nuclide j in S.
- g. collective dose: collective dose vs. individual dose
- h. specific gamma emission: "**Specific gamma-emission (source strength:  $\Gamma$ )**" is defined as the gamma-radiation exposure from 1 MBq point source at 1 meter away, i.e.,

$$\Gamma \equiv \dot{X}(r = 1 \text{ m}, q = 1 \text{ MBq})$$

$$H = \sum_R D_R W_R N_R$$

where,

$W_R =$  **radiation weighting factor**

ex. - 1 for photons of all energies

- 20 for  $\alpha$  particles of all energies

cf. Radiation weighting factor is sometimes called as "**quality factor (Q, QF)**", or "**relative biological effectiveness (RBE)**."

j. distribution factor:

$N_R =$  product of all other modifying factors, mostly due to distribution effects

ex. - 5 for bone seekers such as Sr, Ca due to non-uniform distribution

- 1 for all others

cf.  $N_R$  is sometimes called as "**NF (distribution factor)**."

Problem 2 (10 points): Find the total energy absorbed (in Joules) by a 60-kg human body for 0.5 Gy liver dose.

Data: Mass of liver = 1.2 kg.

Solution:

$$E = (0.5 \text{ J/kg})(1.2 \text{ kg}) = 0.6 \text{ J}$$

Problem 3 (10 points): Find the dose-equivalent rate to bone for 0.5 Gy/hour absorbed dose if the radioactive isotope is Ra, and the type of radiation is alpha.

Solution:

Problem 4 (10 points): Find the absorbed dose rate of soft tissue by exposure of 0.3 MeV photon flux of 1,000 #/sec.cm<sup>2</sup>.

Data:  $(\mu_e/\rho)_t = 31.7 \text{ cm}^2/\text{kg}$  for 0.3 MeV photon.

Solution:

$$E_i = 0.3 \text{ MeV}$$

$$\phi_i = 1,000 \text{ \#/sec.cm}^2$$

$$(\mu_e/\rho)_t = 31.7 \text{ cm}^2/\text{kg} \text{ for } 0.3 \text{ MeV photon}$$

$$\dot{D} = (1.6 \times 10^{-13}) \sum_i \left( \frac{\mu_e(E_i)}{\rho} \right)_{\text{tissue}} E_i \phi_i$$

$$= (1.6 \times 10^{-13})(31.7)(0.3)(1000) = 1.5 \times 10^{-9} \text{ Gy/sec}$$

$$= (1.5 \times 10^{-9} \text{ Gy/sec})(100 \text{ rads/Gy})(3600 \text{ sec/hr}) = \underline{5.4 \times 10^{-4} \text{ rad/hr}}$$

$$= 0.54 \text{ mrad/hr.}$$

Problem 5 (10 points): In 10CFR20, we consider 1 rem = 1 rad = 1 r for X- and  $\gamma$ -rays. Please explain the reason why.

Solution:

$$H = \sum_R D_R w_R N_R \text{ 에서 } w_R = 1, N_R = 1 \text{ 이므로 } 1 \text{ rad} = 1 \text{ rem} \text{ 이다.}$$

$$\text{For soft tissue, } \frac{\left( \frac{\mu_e}{\rho} \right)_{\text{tissue}}}{\left( \frac{\mu_e}{\rho} \right)_{\text{air}}} \approx 1.1 \text{ for all } \gamma\text{-energy ranges.}$$

따라서  $1\text{rad}=1\text{rem}=1r$  이다.

Problem 7 (20 points): Calculate the exposure rate (r/hr) at 3 meters away from an infinite line source of Cs-137 having source strength of 1 mCi/cm.

Data: Cs-137:  $T_{1/2} = 30.0$  year  
 $E_{\gamma} = 0.661$  Mev (95%)  
 $(\mu_e)_{\text{air}} = 0.0035 \text{ m}^{-1}$ .  
 $1 \text{ R} = 5.48 \times 10^{10} \text{ MeV/kg(air)}$

solution:

$$\phi(r) = 2 \int_{x=0}^{\infty} \frac{q[Bq/m]}{4\pi(r^2 + x^2)} dx = 2 \int_{\theta=0}^{\frac{\pi}{2}} \frac{q}{4\pi r r^2 \sec^2 \theta} r \sec^2 \theta d\theta = \frac{q}{4r}$$

$$\begin{aligned} X &= \frac{q}{4r} f_i E_i \left( \frac{\mu_e^{\text{air}}}{\rho} \right) [\text{Mev/kg}] \\ &= \frac{1}{5.48 \times 10^{10}} \times \frac{10^{-1} \times 3.7 \times 10^{10} [Bq/m]}{4 \times 3m} \times 0.95 \times 0.661 [\text{Mev}] \left( \frac{0.0035 [\text{m}^{-1}]}{1.293 [\text{kg/m}^3]} \right) \\ &= 9.564 \times 10^{-6} [R/\text{sec}] = 0.0344 [R/\text{hr}] \end{aligned}$$