QUESTION: I found a simple equation to calculate easily an estimation for the beta dose caused by immersion in a radioactive cloud. I'd like to use a simple equation to quickly calculate gamma dose due to immersion in a finite radioactive cloud, and also for water immersion, to compare with those given at the Environmental Protection Agency's Federal Guidance Report-12. Is it possible?

ANSWER: I do not have copies of the pertinent articles that provide answers to the question, but I can site our work in this area (Chabot et al. 1971; Skrable et al. 1972; Chabot et al. 1974).

A very simple relationship for the immersion gamma dose rate (R) at the center of either a spherical finite air source or spherical water source of radius R can be derived from an equation in a ICRP Publication 2 (ICRP 1959) that gives the dose rate at the center of an assumed spherical organ containing a radionuclide of uniform activity concentration. For a monoenergetic gamma source of uniform concentration, the energy spatial equilibrium dose rate (∞) for an infinite volume source is multiplied by the fraction F of energy spatial equilibrium for a finite source:

$$F = 1 - e^{\mu_{en} R},$$

where μ_{en} is the energy absorption coefficient for the gamma photon for either the air or water source. For more than one photon, the total dose rate at the center of a spherical source can be approximated by summing the contributions from all *i* photons:

$$\dot{D}(R) = \sum_i (1 - e^{\mu_{en_i} R})\dot{D}_i(\infty),$$

where the energy spatial equilibrium dose rate $_i(\infty)$ for the *i*th gamma photon is calculated like that for a beta source. For spherical sources having a small radius R in which all products of $\mu_{en}R$ are small compared to unity for all *i* photons the above equation can be further simplified:

$$\dot{D}(R) = \sum_i \mu_{en_i} R \dot{D}_i(\infty).$$

A further simplification of the above equation is obtained if it is assumed that the energy absorption coefficients have an approximately constant value μ_{en} over the photon energies of interest:

$$\dot{D}(R) = \mu_{en} R \dot{D}(\infty),$$

where $\dot{D}(\infty)$ is the total energy spatial equilibrium dose rate from all photons. For a semispherical air or water source, the maximum gamma dose rate can be approximated as half of that from a spherical source.

Ken Skrable, PhD, CHP

References

Chabot GE, Skrable KW, Wedlick HL. Notes on buildup factors and proposal of a power function analytical representation of the buildup factor. Health Phys 21: 47-474; 1971.

Chabot GE, Skrable KW, A simple formula for estimation of surface dose from photons emitted from a finite cloud. Health Phys 27: 153-155; 1974.

Skrable KW, Chabot GE, Killelea J, Wedlick HL. Evaluation of the environmental significance of the projected Ar-41 release from the Lowell Technological Institute Reactor. Health Phys 21: 49-56; 1972.