

VARSKIN 4 PHOTON DOSIMETRY

The photon dose model implemented in VARSKIN 4 uses a point kernel method that considers the buildup of charged particle equilibrium, transient charged particle equilibrium, photon attenuation, and off-axis scatter. The photon dose model has many of the basic assumptions carried in the beta dosimetry model, namely that the source can be a point, sphere, slab, disk, or cylinder; and that dose is calculated to an averaging disk immediately beneath the surface of skin at a depth specified by the user.

The VARSKIN 4 photon model is based on the simple instance of a volume of tissue exposed to a uniform fluence, Φ_0 , of uncollided photons of energy, E , from a point source in a homogeneous medium,

$$D(E) = \Phi_0 \cdot E \cdot \left(\frac{\mu_{en}}{\rho} \right)_{tissue}. \quad [1]$$

Similarly, a point kernel tissue dose per transition at distance, d , from a point source can be calculated for radionuclides emitting i photons of energy E and yield y ,

$$Dose \left[\frac{Gy}{nt} \right] = \frac{1.6 \times 10^{-10} \left[\frac{J \cdot g}{MeV \cdot kg} \right]}{4\pi d^2 [cm^2]} \cdot \sum_i \left[y_i \left[\frac{photon}{nt} \right] \cdot E_i \left[\frac{MeV}{photon} \right] \cdot \left(\frac{\mu_{en}}{\rho} \right)_{i,tissue} \left[\frac{cm^2}{g} \right] \right]. \quad [2]$$

If the point source is assumed to rest on the skin surface (with a density interface), and a profile of dose with depth in tissue is of interest, Eq. [2] must be modified to account for both the attenuation of photons in tissue and the electronic buildup at shallow depths leading to charged particle equilibrium (CPE). Fully accounting for these phenomena, Eq. [2] becomes,

$$Dose \left[\frac{Gy}{nt} \right] = \frac{k}{d^2} \cdot \sum_i \left[y_i \cdot E_i \cdot \left(\frac{\mu_{en}}{\rho} \right)_{i,tissue} \cdot (f_{cpe})_i \cdot (F_{oa})_i \cdot e^{-\mu_i d} \right]. \quad [3]$$

Federal law requires the determination of average dose to skin over an averaging area, e.g., 10 cm², at some depth in tissue, e.g. 7 mg/cm². In order to determine average dose at depth from a source at the surface, Eq. [3] must be integrated over the averaging area. Integrating the exponential, however, is quite difficult and a step-wise numerical integration of Eq. [3] is necessary. Dose per nuclear transition for a given point source radionuclide with i emissions, averaged over an infinitely thin disk of radius R , at normal depth in tissue h , is therefore calculated by,

$$\dot{D}(h, R) \left[\frac{Gy}{nt} \right] = k \cdot \sum_{j=1}^N \frac{w_j}{d_j^2} \left[\sum_i \left[y_i \cdot E_i \cdot \left(\frac{\mu_{en}}{\rho} \right)_i \cdot (f_{cpe})_{i,j} \cdot (F_{oa})_{i,j} \cdot e^{-\mu_i d_j} \right] \right], \quad [4]$$

where d_j is the point kernel distance between source and dose points, and w_j is the averaging weight.

The numerical integration is conducted from the point source to each of 300 locations along the diameter of the averaging disk. Then, for volumetric sources, point source locations are chosen in equal symmetric increments at 15 point locations in each of the three dimensions within the source volume. Three-hundred calculations of dose from each of 15 x 15 x 15 source point locations are executed for each volumetric source dose estimate (i.e., approximately one million dose calculations).

Attenuation in cover materials and air is accounted for in the VARSKIN 4 photon dosimetry model. As with the beta dosimetry model, up to 5 layers above the skin are allowed, with the air layer only acceptable just above the skin surface. The other material layers are restricted to cotton and/or latex and the source material is assumed to have the same characteristics as air.