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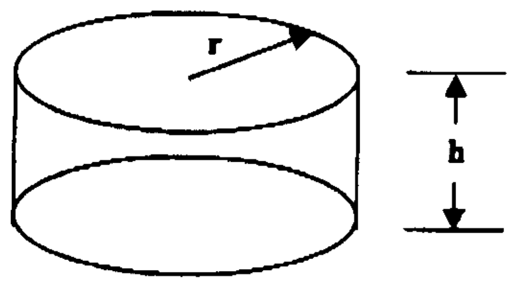
Puerto Rico Extremity Dose Calculation:

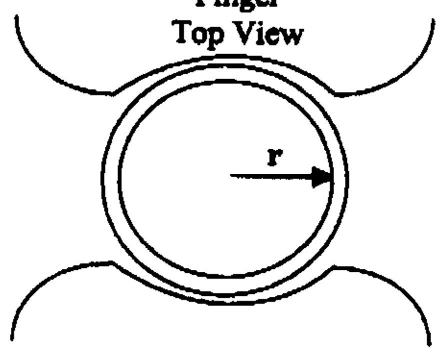
Geometric Considerations:

Angular Distribution:

A B-D 1 cc insulin syringe with its plunger drawn approximates a right cylindrical volume source with radius, **r** = 2.4 mm and height, **h** = 1 mm per division. Where the height is the defined along the length of the syringe barrel.



When the syringe is held between the thumb and index finger, with a pinching motion, the area of contact between the syringe and fingertips is much less than a rectangle of length, **2r** and height, **h**. However, since the fingers eclipse the maximum diameter of the cross sectional area for the syringe barrel the area of interest becomes the rectangle defined by a length of **2r** and a height of **h** this is the source term that will be used.



Additionally; to support this geometry, a photo is provided in attachment 1.

To determine the fraction of photons emitted through the edge of the disc from the volume a simple ratio of the area of interest to the total area can be taken. The fraction **F** then becomes:

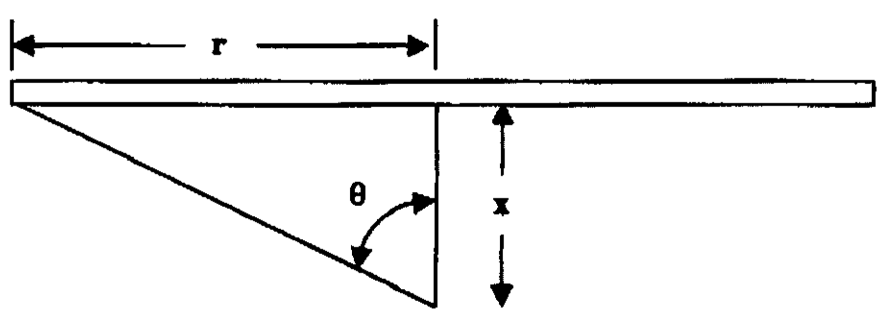
$$F = \frac{2rh}{2\pi\, r\,(r + h)}$$

Distance Reduction:

Since the length is less than the width of a 1 cm^2 reference area (i.e., 1 cm) further geometric reduction for distance needs to be employed. For simplicity, a line source geometry is used to reduce the flux through the wall of the syringe. This argument is further supported since the height is much less than the length of the area of interest (i.e., 1 cm).

Rotating the disk source defined above and viewing it from its edge the rectangle given by length **2r** and height **h** is defined. This is the point of view as seen by the fingertips. Collapsing the disk down onto the diameter by neglecting self-attenuation from the arc-area of the disk, the source can be represented by a thin rectangle. Furthermore, as the observation point is moved away from the surface of the disk edge the thickness of the disk or height of the rectangle plays less and less of a role in the area of interest. With the observation point at distance **x**, where **x** represents the wall thickness of the syringe barrel, a line can be used to represent the profile of the source disk. The use of a line conservative represents the volume source defined by the disk by disregarding self-attenuation and edge effects and assuming the activity is uniformly distributed over the area. Again, since the area of the disk source is much less than 1 cm^2 edge effects from the source can be neglected.

The geometry for the line source approximation takes on the following form:



Where **r** is the radius of the syringe barrel, **x** is the wall thickness of the syringe barrel and θ is the relative angle. Using the standard derivation for exposure at a point from a line source the resulting equation follows:

$$\varphi = \frac{2\theta\, S}{4\pi\, x}$$

Where φ is the uncollided flux in units of $\gamma\ cm^{-2}\ s^{-1}$, S is the source strength in $\gamma\ cm^{-1}$ and x and θ have been previously defined.

The source term, S, can be derived from the activity of the volume source, **A**, the fractional area, **F**, the photon abundance, **Y** and the source length, **2r**. Using these factors and a constant of proportionality the source term is defined as:

$$S = 3.7 \times 10^{7} \frac{A\,F\,Y}{2r}$$

Where the activity is in units of mCi and the radius in units of cm resulting in a source term, S, in units of $\gamma\ cm^{-1}$.

Attenuation and Dose Calculations:

Since only the extremities are involved with this problem only the ***shallow dose equivalent*** will be calculated. The first step is to attenuate the flux, φ, to a depth of 0.007 cm in tissue. This is achieved with the straight ahead approximation of:

$$\varphi_d = \varphi_o e^{-\frac{\mu}{\rho}\rho d}$$

where φ_d is the flux at a depth **d**, φ_o is the uncollided flux, μ/ρ is the mass attenuation coefficient for tissue at the energy of interest and ρ is the density of tissue.

Next, the energy dependent flux, ψ, can be determined by the following equation:

$$\psi = 1.602 \times 10^{-13}\ \varphi_d\ E$$

Where **E** is the energy of the photon field in MeV.

From these factors the shallow dose rate can be determined from the following equation:

$$\dot{D} = 10^{5} \psi \frac{\mu_{en}}{\rho}$$

Where D is the dose rate in rem per second.

Results:

The dimensional values for the syringe are as follows:

Component	Variable	Value
Syringe Barrel Radius	r	2.4 mm
Syringe Wall Thickness	x	1.12 mm
Plunger Height	h	1 mm – 2 mm
Angle (radians)	θ	1.134

From the data provided from the Noel Rodriguez email dated March 21, 2001 and the above equations the following results are derived.

Activity (mCi)	Height (cm)	P	S	Uncollided Flux	Attenuated Flux	Energy Dependant Flux	Dose Rate (Rem/Sec)	40 Doses @11 Sec/Dose (rem)
1	0.1	0.094	6.50E+06	1.05E+07	1.05E+07	2.35E-07	6.36E-04	2.80E-0
4	0.15	0.122	3.40E+07	5.48E+07	5.47E+07	1.23E-06	3.33E-03	1.46E+0
6	0.2	0.145	6.03E+07	9.71E+07	9.70E+07	2.18E-06	5.90E-03	2.60E+0

Based on a information from Alexis Torrado an estimate of the dose should be based on an average activity of 4 mCi with a range of 1-6 mCi. For this reason the dose is assigned as 1.46 rem to the extremity from handling 40 doses for 11 seconds per dose.

Attachment 1

Finger Geometry