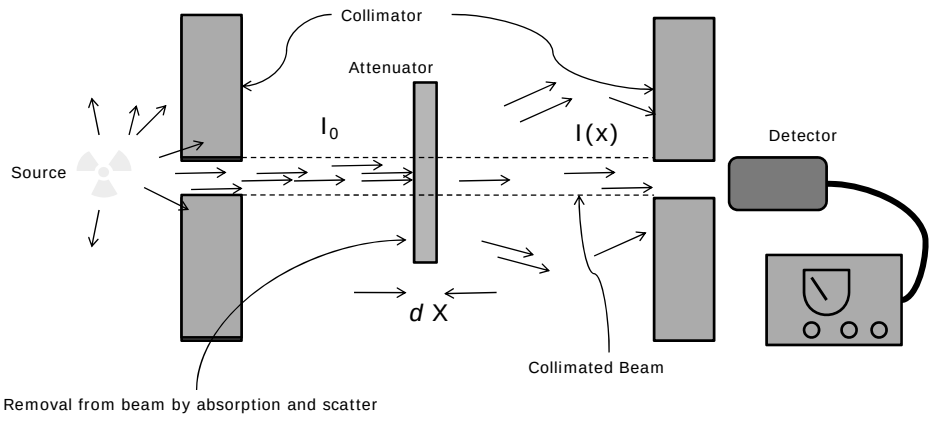
Shielding Review

Dave Tucker

2008 November



Assumptions :
- The collimator is a perfect absorber
- Only the photons emitted towards the detector and not scattered out of the beam in the attenuator will reach the detector

Elements of image adapted from Cember

In traversing a thin element of the absorber, a small fraction of the photons in the beam are removed.

$$I(x+dx) = I(x) - \mu \cdot I(x) \cdot dx$$

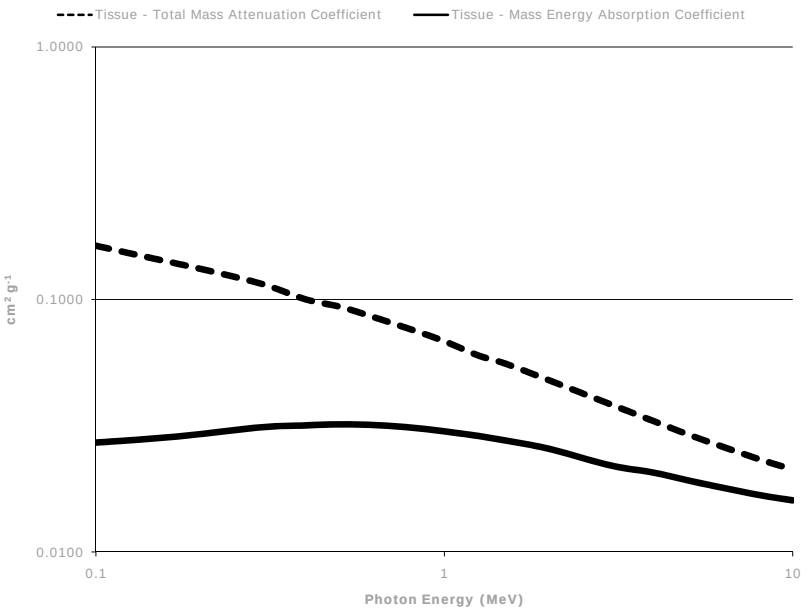
$$\frac{dI(x)}{dx} = \mu \cdot I(x)$$

$$\frac{dI(x)}{dx} - \mu \cdot I(x) = 0$$

$$I(x) = I_0 \, e^{-\mu \cdot x}$$

Attenuation Coefficients

- Linear attenuation coefficient
  - μ_ℓ (cm^{-1})– attenuation per unit thickness
- Mass attenuation coefficient
  - μ_m (cm^2g^{-1}) – attenuation per unit mass thickness
  - $\mu_\ell = \mu_m \times \rho$ μ_m also written (μ/ρ)
- Mass energy absorption coefficient
  - Reflects energy transfer from photon field rather than attenuation
  - Related to dose deposition from photons
- Many other coefficients for particular interactions



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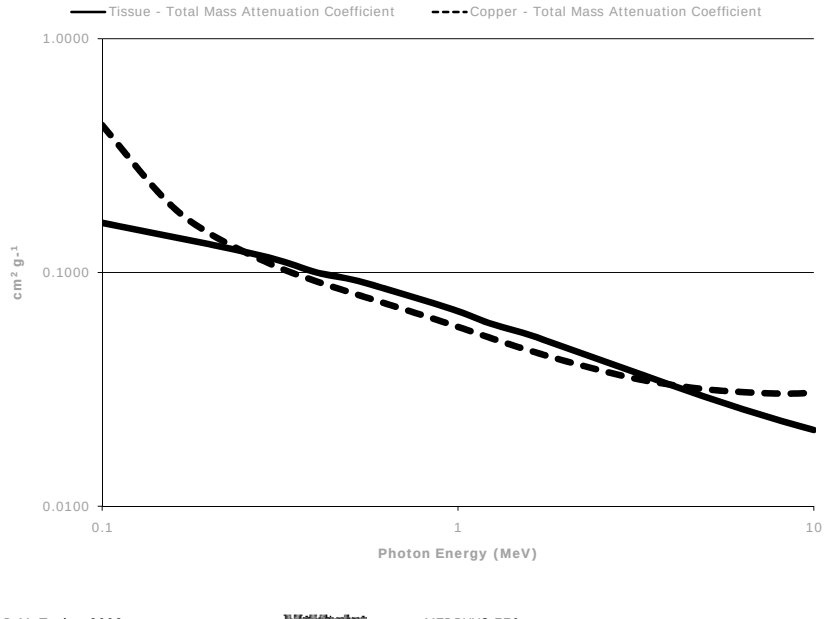
MEDPHYS 776
UN0805

OH 5



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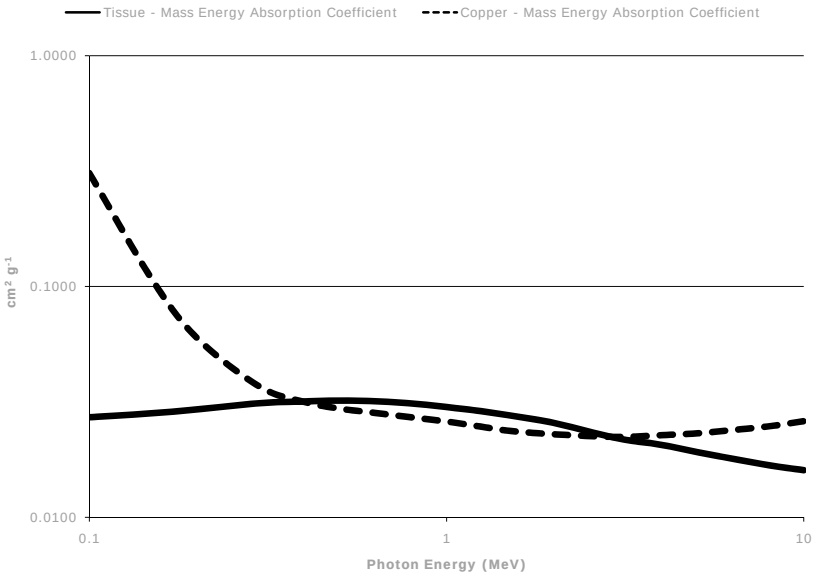

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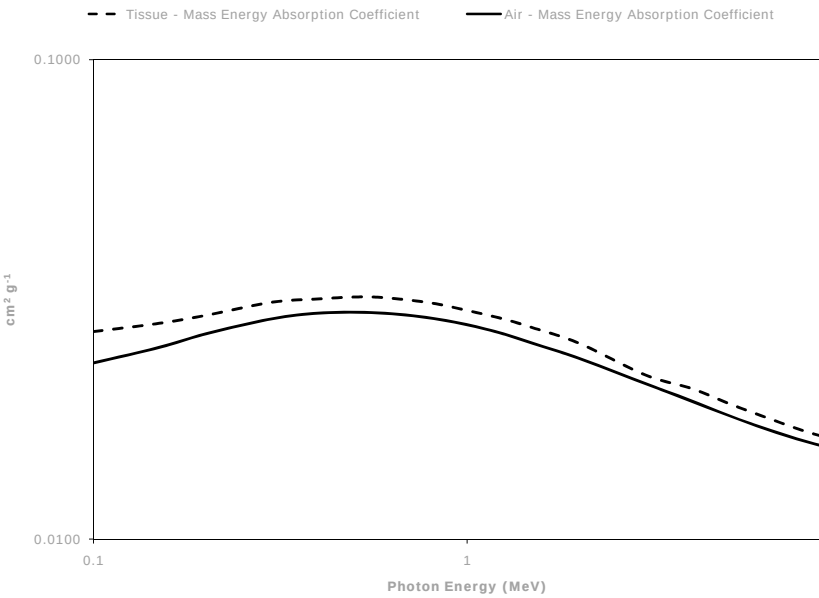

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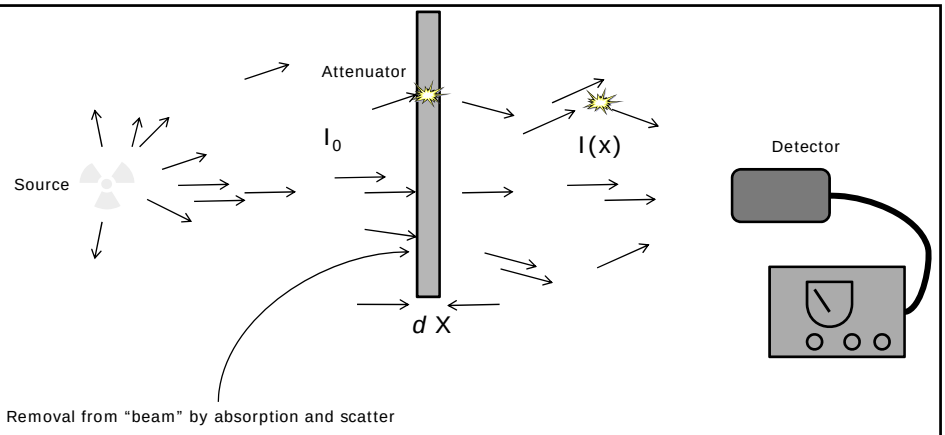
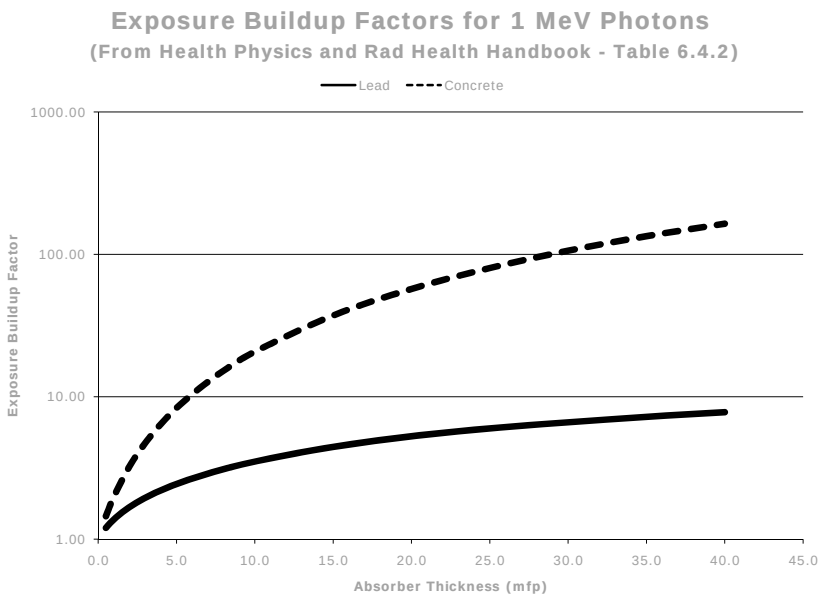


Broad Beam Geometry :
- Some photons initially not travelling to detector are scatted towards detector
- Some photons scattered away from "beam" are scattered back towards detector

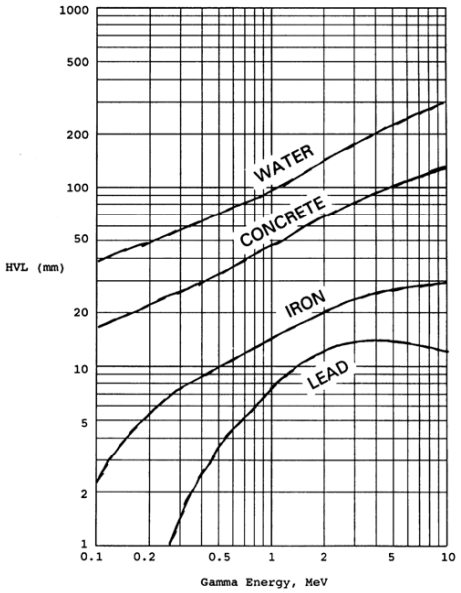
Buildup accounts for the increase in dose rates above what would be expected based on good geometry attenuation.

$$I(x) = B(\mu \cdot x) I_0 \, e^{-\mu \cdot x}$$
$$D(x) = B(\mu \cdot x) D_o \, e^{-\mu \cdot x}$$

Buildup factors are published for different parameters – such as exposure and energy absorption.
The Buildp factor is a function of the thickness of the absorber – usually expressed as the number of mean free paths (mfp). The mean free path is 1/μ. Thus when x = 1 mfp, μ x = 1. In one mfp, the parameter of interest (e.g. exposure) drops off by e^{-1}.



- Half Value Layers (HVLs) are sometimes used in shielding assessments.
- Analogous to Half-Life for decay.
- ~7 HVLs for 99% reduction. 10 HVLs for 99.9% reduction.
- Tenth Value Layers also used.
- Must use caution as the spectrum shifts.



Source: NB Power Radiation Protection Green Book by Burnham

Radio nuclide	Half Life	Main Gamma Energies (MeV)	Half-Value Layers			Tenth-Value Layers		
			Concrete (cm)	Steel (cm)	Lead (cm)	Concrete (cm)	Steel (cm)	Lead (cm)
Cs-137	27 y	0.66	4.8	1.6	0.65	15.7	5.3	2.1
Co-60	5.24 y	1.17 and 1.33	6.2	2.1	1.20	20.6	6.9	4.0
Au-198	2.7 d	0.41	4.1	--	0.33	13.5	--	1.1
I-192	74 d	0.13 to 1.06	4.3	1.3	0.60	14.7	4.3	2.0
Ra-226	1622 y	0.047 to 2.4	6.9	2.2	1.66	23.4	7.4	5.5

Source: Health Physics and Radiological Health Handbook

Sample Problem

- See Shielding and Activation Sample Problem #1.