Journal of Radiation Research and Applied Sciences 8 (2015) 439–445

HOSTED BY
ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect
Journal of Radiation Research and Applied Sciences
journal homepage: http://www.elsevier.com/locate/jrras

Investigation of some radiation shielding parameters in soft tissue

Danial Salehi [a,*], Dariush Sardari [a], M.S. Jozani [b]

[a] Department of Radiological and Nuclear Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[b] Faculty of Engineering, Islamic Azad University, South Tehran Branch, Tehran, Iran

ARTICLE INFO

Article history:
Received 3 December 2014
Received in revised form
28 February 2015
Accepted 16 March 2015
Available online 30 March 2015

Keywords:
Energy absorption buildup factor
Soft tissue
Mass attenuation coefficient
Mass absorption coefficient
Effective atomic number

ABSTRACT

The photon interactions with the soft tissue have been discussed mainly in terms of mass attenuation coefficient, mass energy absorption coefficient, kerma relative to air, effective atomic number and energy absorption buildup factor in the energy range 0.01–10 MeV and penetration depth up to 40 mfp (by using GP fitting method). Over past 2 decades, interest has been growing for theoretical and computational works on photon buildup factor in soft tissue. Actually, besides dosimetry, in radiation therapy and imaging the buildup of X- and gamma photons introduces remarkable error.

1. Introduction

Since photons viz. gamma and X ray widely used in radiation therapy and medical imaging, the problem of flux deposition in the body and their biological effects is very important in shielding analysis. The mass attenuation coefficient, μ/ρ, and the mass energy–absorption coefficient, μ_{en}/ρ, are basic quantities used in calculations of the penetration and the energy deposition by photons (x-ray, γ-ray, bremsstrahlung) in biological, shielding and other materials (Hubbell & Seltzer, 1995).

On the other hand buildup factor is an important parameter in predicting and estimating the distribution of photon flux in irradiated object and calculation of radiation dose received by the biological molecules (Chilton, Shultis, & Faw, 1984; Sardari and Baradaran, 2010; Sardari, Abbaspour, Baradaran, Babapour, 2009). The buildup factors define in two terms: exposure in the air after penetration through the absorber or shielding material that called the "Exposure Buildup factor" (EBF). Other types of buildup factors also exist, in particular "Energy Absorption Buildup Factor" (EABF) for energy deposition in an absorbing medium and dose buildup factors in absorbing media (Martin, 2006).

Up till now, studies regarding EABFs in biological samples have been widely made using the well-known methods that is, geometric progression (GP) fitting method, generalized feed-forward neural network (GFFNN), and Monte Carlo N-

* Corresponding author. Tel.: +98 2144868401.
E-mail addresses: d.salehi@srbiau.ac.ir, da.salehi@yahoo.com (D. Salehi).
Peer review under responsibility of The Egyptian Society of Radiation Sciences and Applications.
http://dx.doi.org/10.1016/j.jrras.2015.03.004

Particle (MCNP) codes (Harima, Sakamoto, Tanaka, & Kawai, 1986; Kucuk, Manohara, Hanagodimath, & Gerward, 2013; Kurudirek & Ozdemir, 2011; Manjunatha & Rudraswamy, 2011; Manohara, Hanagodimath, & Gerward, 2010; Manohara, Hanagodimath, & Gerward, 2011; Sidhu, Singh, & Mudahar, 1999, 2000; Mann & Sidhu, 2012; Mann, Kurudirek, Sidhu, 2012; Sardari et al., 2009).

Recently Sardari and Baradaran (2010) described a new relationship for estimating buildup factor as a function of penetration depth, Compton scattering, and energy absorption cross sections in water and soft tissue. In other work Sardari and Kurudirek developed this semi empirical equation approach to the data obtained through five parameter GP fitting method to the energy absorption buildup factor for soft tissue, water, and Hydrogen, Carbon, Nitrogen and Oxygen based some dosimetric materials (Sardari & Kurudirek, 2012). In this study some radiation shielding parameters such as the mass absorption coefficient, kerma relative to air, the equivalent atomic number and energy absorption buildup factors were investigated in the soft tissue.

2. Material and methods

2.1. Mass attenuation and absorption coefficients

The mass absorption coefficients of the soft tissue were determined using the transmission method according to Lambert–Beer's law ($I = I_0 \exp - \mu/\rho^* X$) where I_0 is the intensity of the incident beam, I(x) is the intensity after traversing a layer of material with mass-per-unit-area "X", and μ, the linear attenuation coefficient, is the probability of interaction per unit distance in an absorbing medium.

The mass attenuation coefficient ($\mu_m = \mu/\rho$) is of more fundamental importance than linear attenuation coefficient (μ) because all mass attenuation coefficients are independent of the density and physical state (gas, liquid or solid) of the absorber. This coefficient can be a useful coefficient because only the atomic composition of the attenuator is taken into account and not the individual density of the material (Hopkins, 2010).

The mass attenuation coefficient is a measure of the average number of interactions between incident photon and matter that occur in a given mass-per-unit area thickness of the material. It is distinguished sharply from the absorption coefficient which is always a smaller quantity and absorption coefficient measures the energy absorbed by the medium (Gupta & Sidhu, 2014).

Radiation exposure or absorbed dose of photons is determined by the amount of energy deposited by the various photon interactions as they traverse a medium such as tissue. Since some interactions produce radiant energy that carries energy out of the medium, the attenuation coefficient μ cannot be used to determine energy deposition in a medium. Consequently, a linear energy absorption coefficient μ_{en} has been defined that accounts for this loss:

$$\mu_{en} = \mu - (\textit{scattering probability} + \text{other low probability interactions}) \quad (1)$$

Values of μ_{en} are based only on the energy absorbed into the medium; therefore, energy losses due to Compton-scattered photons, bremsstrahlung, and other radiative processes following interaction have been subtracted because they are very likely to leave the medium. The mass energy absorption coefficient μ_{en}/ρ with units of cm^2/g is the most useful form for determining radiation exposure or dose when a flux of x-rays or gamma rays is known or can be determined (Martin, 2006).

2.2. Effective atomic numbers

In order to define an effective atomic number (Z_{eff}) (Kurudirek, 2011; Sing & Badiger, 2014) in the soft tissue, we need to calculate two parameters:

1 The total electronic cross section (σ_e) for the individual element is calculated using the following equation:

$$\sigma_e = \frac{1}{N_A} \sum \frac{f_i A_i}{Z_i} \left(\frac{\mu}{\rho}\right)_{en} \quad (2)$$

where $f_i = n / \Sigma_i n_i$ denotes the fractional abundance of the element i with respect to the number of atoms such that $\sum_i^n f_i = 1$ is the atomic number of ith element.

2 The effective atomic cross section (σ_a) is calculated using the equation

$$\sigma_a = \frac{1}{N_A} \sum f_i A_i \left(\frac{\mu}{\rho}\right)_{en} \quad (3)$$

where μ_{en}/ρ is the mass energy absorption coefficient of the soft tissue, f_i is the fraction by weight of element i and A_i is the atomic weight of the element i.

The σ_e and σ_a are related to the effective atomic number, Z_{eff} of a composite material through the following relation.

$$Z_{eff} = \frac{\sigma_a}{\sigma_e} \quad (4)$$

The effective atomic numbers for the soft tissue were also calculated using Auto-Z_{eff} soft ware that collected in Table 1 (Taylor, Smith, Dossing, & Franich, 2012).

2.3. Kerma relative to air

Kerma of the soft tissue relative to air is defined as:

$$k_a = \frac{k_{soft\ tissue}}{k_{Air}} = \frac{(\mu_{en}/\rho)_{soft\ tissue}}{(\mu_{en}/\rho)_{Air}} \quad (5)$$

The mass energy absorption coefficient, μ_{en}/ρ for a mixture is calculated using:

$$(\mu/\rho)_{en} = \sum_i^n w_i (\mu_{en}/\rho)_i \quad (6)$$

where w_i and $(\mu_{en}/\rho)_i$ are the weight fraction and the mass energy absorption coefficient of the ith constituent elements present in the soft tissue. The values of (μ_{en}/ρ) have been taken from the literature (Martin, 2006; Sing & Badiger, 2014).