X-ray spectrometry applied for determination of linear attenuation coefficient of tissue-equivalent materials

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The correlation between image quality and the potentially harmful biological effects of radiation can be obtained from the relationship between physical parameters of the image, such as contrast, noise, spatial resolution, and absorbed dose. Periodic tests required on x-ray imaging equipment are applied using phantoms. Their use is essential in modern diagnostic imaging to provide quantitative, reproducible information on image quality and dose. Production of these phantoms depends on tissue-equivalent materials, for simulating specific tissues or materials of dosimetric interest. In a methodology previously developed [1], the linear attenuation coefficient of a material is fitted to the reference material. This method was used to obtain samples of polymer-based materials equivalent to water. In order to assess the quality of the produced material, primary and transmitted narrow beams x-ray spectra were measured using a CdTe spectrometer (Amptek, inc) [1]. The radiation beams were generated by a tungsten-target x-ray machine (SMART 300HP, YXLON, Germany) using voltages from 60 to 120 kV. These spectra were transmitted by different thickness of the tissue-equivalent materials samples. For each set of sample-thickness-voltage, the mean linear attenuation coefficient, $\bar{\mu}(E)$, was calculated using the equation (1)[2]:

$$\bar{\mu}(E) = -\frac{1}{M}\sum_{i=1}^{M}\frac{1}{x_i}\ln\left[\frac{N(E,x_i)}{N(E,0)}\right] \qquad (1)$$

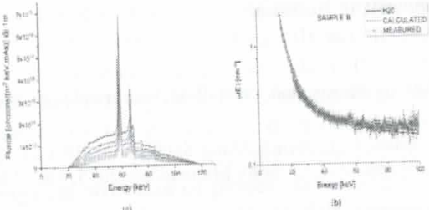

Figure 1 – (a) Primary x-ray spectrum (black line) and spectra transmitted by different thicknesses of sample B; (b) linear attenuation coefficient of water (black line), calculated using the developed methodology (red line) and calculated (blue points) using the transmitted spectra according to the equation (1).

In this equation, $N(E,0)$ is the primary x-ray spectra and $N(E,x_i)$ is the x-ray spectra transmitted by a thickness x_i of a given sample and M is the number of thicknesses studied. Figure 1(a) show as an example primary and transmitted spectra measured using 120 kV with one of the develop samples. Figure 1(b) presents the result of the application of equation (1) to this set of spectra. The thicknesses of the samples variated from 1 to 6.4 cm. The figure also plots the linear attenuation coefficient of the water and the calculated using the mathematical model [1]. The differences between the measured and the target μ(E) was lower than (7.0±0.3)% in the range of energies from 20 to 80 keV. Therefore, the authors consider the developed material a good option to be used as a water-equivalent material, and the experimental method adequate to its quantitative evaluation.

Keywords: phantoms, tissue-equivalent, attenuation coefficient

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