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X-ray spectra and doses

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HIGHLIGHTS

- X-ray spectra were calculated using Monte Carlo method.
- Spectra were produced by 150 keV electrons interacting with Mo, Rh and W targets.
- Calculations were performed with and without Al filter.
- With the spectra, the K_{Air}, H*(10) and Hp(10, 0°) were estimated.

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ABSTRACT

Using the Monte Carlo method the x-ray spectrum produced by 150 keV electrons colliding with W, Rh and Mo targets were calculated. The x-ray spectra were calculated to 20, 50, and 100 cm from the focal point. In order to analyze the effect of the filter, calculations were carried out with and without filter. The spectra were used to estimate the Kerma in air, the Ambient dose equivalent, and the Personal dose equivalent. The spectra were integrated in energy to obtain the total photon fluences. Calculated spectra depend on the type of target having the continuous spectrum due to bremsstrahlung and the characteristics x-rays. The Al filter eliminates the low-energy photons; however no effect is noticed when the photon energy is larger than 40 keV. The largest effect of dose reduction due to the filter was noticed to 20 cm for the Kerma in air.

1. Introduction

One third of all important medical decisions are based on the information obtained by diagnostic radiology. In radiology, the chest radiography is the study used with high frequency because it generates images of the heart, lungs, airways, blood vessels, spine bones, trachea, and chest bone, allowing its evaluation (Vassileva, 2002). There is no doubt about the role of radiographies in the diagnosis; however, due to the ionizing-radiation effect on human tissues is necessary the development of radiation protection strategies (Poston, 2005).

In diagnostic radiology the patient's dosimetric control is very rare, even when several radiographies are taken to the same patient. Thus, have been reported situations where the dose receive is significant (Ng et al., 1998), so it is important to seek evaluation mechanisms to estimate the level of dose received by a patient (IAEA, 2007). The use of x-rays for diagnostics still has the challenge of having images with good quality aiming the lowest dose (ICRP, 1991, UNSCEAR, 2000). In order to evaluate the dose levels, the dose at the surface entrance is measured. The air kerma on the entrance surface is also used; normally these measurements are carried out using a phantom (Shrivastava, 1981). Both dosimetric magnitudes are used as indicators and compared against the reference levels (Roussin et al., 2004).

Another resource is to use Monte Carlo methods to estimate the dose, in order to have good estimations is necessary to know the elemental composition of human organs and tissues, and to have good information about the x-ray spectrum, that has a continuous part due to bremsstrahlung and a discrete part due to the type of target. The amount of photons is related to the current and the photon penetration depends upon the voltage. To avoid low energy photons that do not contribute to the image quality a filter is used.

The aim of this study was to calculate the x-rays spectra, with and without filter, produced in the interaction of 150 keV electrons with W, Mo, and Rh targets, and to estimate the values of the

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ambient dose equivalent, the kerma in air, and the personal dose equivalent.

2. Materials and methods

The MCNP5 code (X-5 Monte Carlo team, 2003) was used to estimate the x-ray spectra produced when a monoenergetic beam of 150 keV electrons interacts with three types of targets: Mo, Rh and W. The spectra were calculated with and without filter and the values of Ambient dose equivalente, H*(10), the Kerma in air, K_{Air}, and the Personal dose equivalent, Hp, were estimated. In the calculations the amount of histories was large enough to have Monte Carlo uncertainties less than 5%.

The x-ray tube was modeled as is shown in Fig. 1. It has 1 cm-thick lead shielding the source term was modeled as point-like source located to 3.5 cm from the target that was modeled as a truncated cone. In the simulation electrons were sent to the cone surface having 40° from the electrons incoming direction. To eliminate the low energy photons 1 mm-thick filter made of Al was included.

The filter was placed 5.5 cm below the focal point, being the point where the unidirectional electrons collide with the target.

In order to estimate the x-ray spectrum, $\Phi_X(E)$, cells were sited 20 cm below the focal point. To estimate the H*(10), the K_{Air}, and the Hp(10,0°), cells were allocated to 20, 50 and 100 cm below the focal point. The dosimetric quantities were calculated using Eq. (1) (Vega-Carrillo et al., 2009).

$$\Delta = \int_E \Phi_X(E)\ \delta(E)\ dE \tag{1}$$

Here, Δ is the dose of interest, $\Phi_X(E)$ is the x-ray spectrum, and $\delta(E)$ are the photon fluence-to-dose conversion coefficients from the ICRP 74 (ICRP, 1996), shown in Fig. 2. In the calculations the energy varies from 10 up to 150 keV.

The total photon fluence, ϕ, was calculated using Eq. (2)

$$\varphi = \int_E \Phi_X(E)\ dE \tag{2}$$

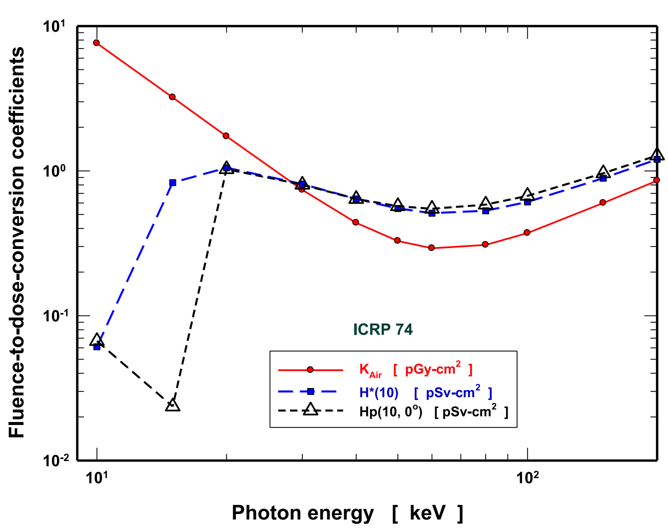

Fig. 1. Fluence-to-dose conversion coefficients.

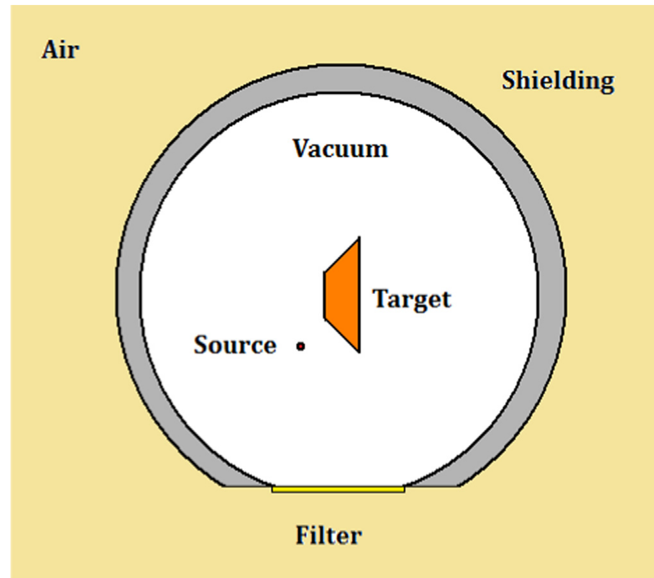

Fig. 2. Model of the x-ray tube.

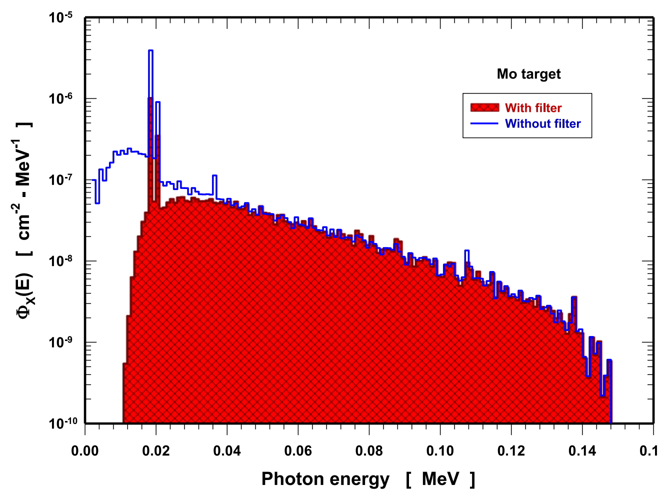

Fig. 3. X-ray spectra with and without filter produced by 150 keV electrons interacting with Mo target.

3. Results and discussion

3.1. X-ray spectra

In Fig. 3 are shown the x-ray spectra per electron, produced by the Mo target with and without filter. X-ray spectra are estimated to 20 cm from the focal point.

The spectra have the continuous part, due to the bremsstrahlung, and the discrete contribution (peaks). The largest photon energy in the continuous spectrum is 150 keV. In the discrete spectrum the K_α, K_β x-rays are shown. These peaks have 17 and 20 keV which are characteristic of Mo whose energies are $K_\alpha = 17.478$ keV, and $K_\beta = 19.607$ keV.

When filter is in place photons below 40 keV are absorbed and attenuated. Those low energy photons could deliver an undesirable dose in the patient skin. The filter does not affect the x-rays with energy above 40 keV.

The total x-ray fluence per electron to 20 cm without filter is 1.10E(−5) cm^{-2} and with filter is 4.20E(−6) cm^{-2}. Without filter the total photon fluence is approximately 2.62 times larger than the total fluence with the filter.

In Fig. 4 the x-ray spectra per electron produced by the Rh