SPECTROSCOPY OF PATIENT SCATTERED X-RAYS USING GE DETECTORS

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INTRODUCTION

One of the main tasks in radiation protection is the reliable determination of risk relevant dose quantities-like organ doses, effective dose or partial body doses-for exposed persons. In cases, when a more detailed description of an exposure situation is demanded, the radiation field has to be analysed with regard to the type of radiation, the spectral energy distribution and the direction of incidence, to convert personnel dose (or any other measured dose) into a risk relevant dose descriptor. Especially in context with the increasing number of long lasting interventional examinations or treatments in diagnostic radiology this became a pressing problem in the recent past.

A catalogue of spectra was prepared (1) which contains spectra of radiation scattered by a water phantom in dependence of scatter angle and tube voltage. In addition, for rougher estimates or when measured dose values are not available, approximate air kerma values in a distance of 50 cm to the centre of the phantom are presented.

METHOD

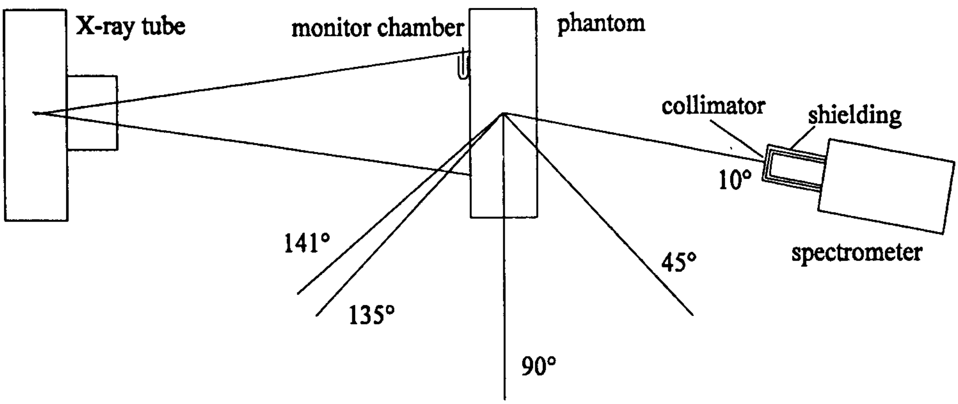

Figure 1. Experimental arrangement

A water filled perspex phantom (30 cm x 30 cm x 15 cm) was irradiated in 70 cm focus to phantom distance. Size of the central rectangular field: 16 cm x 16 cm. The measurements were performed at a diagnostic X-ray unit (Polymat 50 with a Pantex 125 X-ray tube, total filtration 3 mm Aluminium) operated in fluoroscopic mode. The spectrometer was equipped with a cylindrical (height: 50 mm; diameter: 56 mm) high purity Germanium detector (EG&G Ortec, GMX-25190 with Beryllium entrance window). To avoid distortion of the measured pulse height distributions by pile-up effect, the beam impinging onto the detector was highly collimated (beam diameter: 1.4 mm). In all other directions the detector was shielded by 3 mm copper and 12 mm lead.

Spectra were measured for the indicated directions (fig. 1) at tube voltages of 52 kV and at 60 kV to 110 kV in steps of 10 kV. Because of the small aperture of the narrow collimator it became necessary to position the spectrometer in a comparatively large distance of 212 cm to the centre of the phantom to register all the radiation scattered by the phantom into the considered direction. To achieve the desired spectra measured pulse height distributions were corrected in a stripping procedure using detector response functions calculated by Monte Carlo methods for the detector and collimator arrangement in the spectrometer (2,3). Air kerma in the phantom to collimator distance was calculated on the basis of spectral photon fluence and diameter of the collimating diaphragm.

To provide approximate values for the integral photon fluence and for air kerma in a realistic distance (50 cm) to the phantom centre dependence of air kerma from distance along the indicated directions (fig. 1) was measured by means of a 1000 cm^3 ionisation chamber (20341, PTW). Thereby a 0.2 cm^3 soft X-ray chamber (R 17927, PTW) served as monitor in the entrance plane of the phantom to compensate for fluctuations of the X-ray tube output.

RESULTS and DISCUSSION

Figure 2 shows as an example one of 35 spectra of the catalogue. The spectrum is presented in arbitrary units for energy intervals of 1 keV, normalised to unity in the peak interval. As to be expected the characteristic K-lines are shifted towards lower energies and the spectrum with a mean photon energy of 51.1 keV is in total significantly harder than the primary spectrum meeting the phantom with a mean photon energy of 43.5 keV (4).

To validate the applied methods (measurement and stripping procedure) selected primary spectra were measured in a modified experimental arrangement and compared with data from other publications (4,5). Part of the scattered spectra could also be compared with spectra calculated by Monte Carlo Methods (6). In both cases the agreement was good.

The absolute values for air kerma and integral photon fluence per unit of the product of tube current x exposure time (mAs), as presented in figure 2, depend strongly on the geometrical arrangement of X-ray tube and phantom (distance, field size), the condition of the X-ray tube and the not strict proportionality between mAs value and X-ray tube output. Consequently they can only be considered as rough approximate values.

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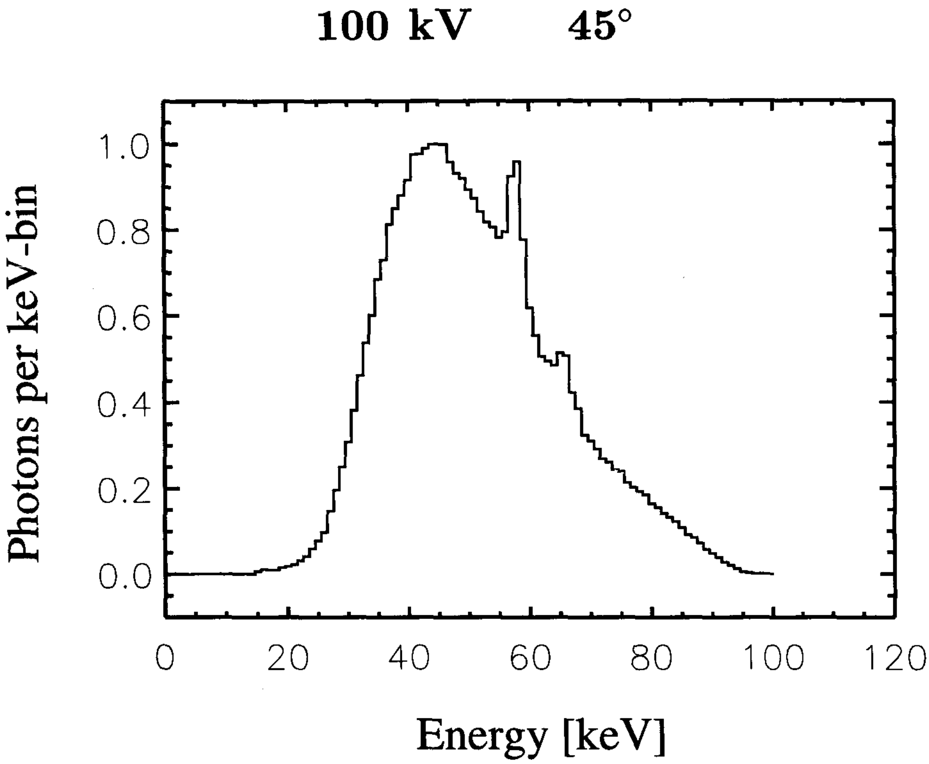

keV	1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	1	0	0	1	1
20	2	3	4	5	7	9	14	19	25	30
30	38	46	53	60	68	72	81	85	88	91
40	97	97	98	99	100	99	95	93	91	89
50	87	84	81	80	78	79	92	95	77	61
60	55	50	49	48	51	50	42	38	32	31
70	29	26	26	24	23	21	20	19	18	16
80	15	14	13	12	10	9	8	7	5	4
90	3	2	2	1	0	0	0	0	0	0

Parameters during irradiation	values
Filtration	3 mm Al
Field size on phantom	16 cm · 16 cm
Mean photon energy	51.1 kV
Air kerma at 50 cm/mAs	0.158 $\frac{\mu Gy}{mAs}$
Photon fluence at 50 cm	419788 $\frac{photons}{mAs\ cm^2}$

Figure 2. Spectrum of scattered radiation for 45° scattering angle and 100 kV tube voltage.