(DETERMINATION OF DIAGNOSTIC X-RAY TUBES OUT-PUT IN TERMS OF H*(d) FOR IEC QUALITIES AND FOR BEAMS TRNASMITTED BY LEAD FILTERS

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Abstract. The X-ray spectra to the energy range between 50 to 125 kVp, applied in diagnostic radiology, were previously determined experimentally using a high-purity germanium detector, (HP)Ge, coupled to a multichannel analyzer. In this work the diagnostic X-rays tubes out-put were experimentally determined in terms of ambient dose equivalent . The measurements were performed in the energy range between 50 to 125kVp for IEC 1267 qualities for primary X-ray beams and attenuated x-rays beams using aluminium filters with thickness between 2.5 and 42.5mm. It was also performed measurements for X-rays beams transmitted by lead filters with thickness between 0.3 and 0.7mm; in this case it was necessary to estimate the effective dose of the same way that it is done for radiology diagnosis room shielding projects. The thickness of lead equivalent protection layers were calculated estimating the air kerma or the weekly equivalent dose at the interest point. Aiming to stand! ardise the X-ray out-put of the diagnostic equipments it was necessary to determine the out-put in terms of the operational quantity recommended by the ICRU 57, the ambient dose equivalent. The obtained results show that the method of determine attenuation factors using air kerma, in same cases, can conduct to a over estimation of the obtained attenuation in terms of effective dose, that is the quantity used as limit to the occupational risks. In this way, it is probably that several radiology diagnosis room shielding have been calculated under estimating the lead thickness.

Introduction

The use of medical ionizing radiation, which benefits patients greatly, contributes significantly to the individuals and the population rise of exposition. The diagnostic radiology is the greatest source of ionizing radiation used by the man. At least one fourth of the World population has already done one kind of unnecessary radiological exam [1].

The International Commission of Radiological Protection (ICRP), in its publishing ICRP 60[2] recommends that radical efforts should be done in order to reduce unnecessary exposition, specially if they can be done without damaging the benefit caused by the diagnostic.

Among many problems that can occur with the x-ray equipment, one of them is the x-ray output tube change. The x-ray output [which is measured in Gy $(mA.s)^{-1}$ or mR $(mA.s)^{-1}$] is mainly influenced by the tube potential (kVp), and also by the current (mA) and the exposure time (s). They can also be influenced by other factors, such as half value layers (HVL), target angle, etc,.

The ICRP [2] recommends a system of numerical specifications based on dose equivalent in many organs of an individual and in the moderate sum of the dose equivalent in some organs – effective dose. Such unmeasurable quantities can be estimated of the dose equivalent determined in appropriate places in acceptable receptors. The ICRU 39[3], in its publishing, recommends a tissue sphere of 30 cm of diameter as an acceptable receptor for estimative of these new protection quantities. The ambient dose equivalent is the operational quantity, indicated by the ICRU, recommended for monitoring the work ambient with radiation.

In this work, the x-ray output was measured in terms of the ambient dose equivalent (for radiation strongly penetrating). For that, it was used a dosimetric system and spheric phantom made by PMMA(polymethyl methacrylate) in qualities of x-ray applied in diagnostic radiology (50 to 150 kVp).

Measurements were done when the photon beams went through the layers of the material used as shielding, for instance, the lead. The quantity, H*(10), was compared with the ambient dose equivalent in other depths in the PMMA spheres, H*(50) and H*(60), also measures, in turn, were compared to results obtained by Monte Carlo simulation.
The measurements were made in an interval from 50 to 125 kVp in the qualities of the IEC 1267 [4] for beams of primary x-ray and beams of attenuated x-ray with thickness of aluminium from 2.5 to 42.5 mm.

Methodology

The x-ray output in terms of kerma in the air were made for the qualities and conditions indicated in Tables 1 and 2 in beams of x-ray incident and transmitted by Al or Pb. The current used in the measurements had a minimum of 10 mA and a maximum of 100 mA. The kerma measurement in the air was made in the geometric centre of the ionization chamber positioned at 100 cm of distant from the focus point and for a field of 33 x 33 cm^2. The kerma measurements were done with an ionization chamber model 77334/2035 with a sensible volume of 1 cm^3 connected to an electrometer model PTW – UNIDOS. The kerma in the air was measured by the following equation:

$$K_{air} = K_Q \times \frac{K_p}{K_m} \times N_{air} \times M \qquad (1)$$

Were:
M is the direct reading of the ionization chamber (Gy);
N_{air} is the calibration factor of the calibrated chamber in the standard laboratory;
K_Q is the correction for the radiation quality;
K_p is the reading correction in relation to a source of ^{14}C when the chamber is calibrated;
K_m is the present correction reading in relation to source ^{14}C.
The measurement with the ionization chamber were repeated 10 times for each quality of the radiation beam and the value of the M reading was obtained as being the arithmetic average of the ten readings.

Table 1. Energy spectrum characterization parameters of the incident x-ray beams in the patient (unattenuated beam) [5]

Qualities	Nominal Tension(kV)	First HVL (mm Al)	Second HVL (mm Al)	Coefficient of homogeneity
QI	50	1,8	2,6	0,69
QII	60	2,2	3,1	0,71
QIII	70	2,5	3,8	0,66
QIV	81	2,8	4,4	0,64
QV	90	3,1	5,5	0,56
QVI	102	3,6	6,1	0,59
QVII	125	4,4	7,6	0,58

Table 2 Energy spectrum characterization parameters of the standardized beams as transmitted by the patient (attenuated beam) [5]

Qualities	Nominal Tension(kV)	First HVL (mm Al)	Second HVL (mm Al)	Coefficient of homogeneity
QVIII	50	3,7	4,2	0,88
QIX	70	6,5	7,2	0,90
QX	90	8,8	9,9	0,89
QXI	125	11,5	11,7	0,95

Results and discussion

For standardizing the x-ray equipments in terms of the new operational quantities defined by ICRU [3,6,7] it is necessary that their x-ray outputs be determined in terms of the ambient dose equivalent, H*(10). The Figs. 1 and 2 show the x-ray output, in terms of the kerma in the air and of the H*(d) of the x-ray equipment Siemens model Polymat 50, for unattenuated beams and attenuated beams with thickness of Al and Pb. The x-ray output determination in terms of ambient dose equivalent, H*(d), of the x-ray equipment Siemens Polymat 50, was done from the measurement of the kerma in the air, with the ionization chamber, multiplied by the conversion coefficient $H^*(d)/K_{air}$ determined in the reference [8].
The Fig. 3 displays the x-ray output measured in this paper and calculated by Monte Carlo code [9], in terms of H*(10) for x-ray beams diagnostic unattenuated (total filtration 3.7 mm Al). The values showed in the figure illustrate a maximum standard deviation of 10% in relation to values obtained by calculus, found in the literature [9]. This difference is included in our experimental uncertainties. Most of the x-ray equipments used in diagnostic radiology have total filtration between the minimum recommended of 2.5 mm Al until the maximum of 4.0 mm Al..

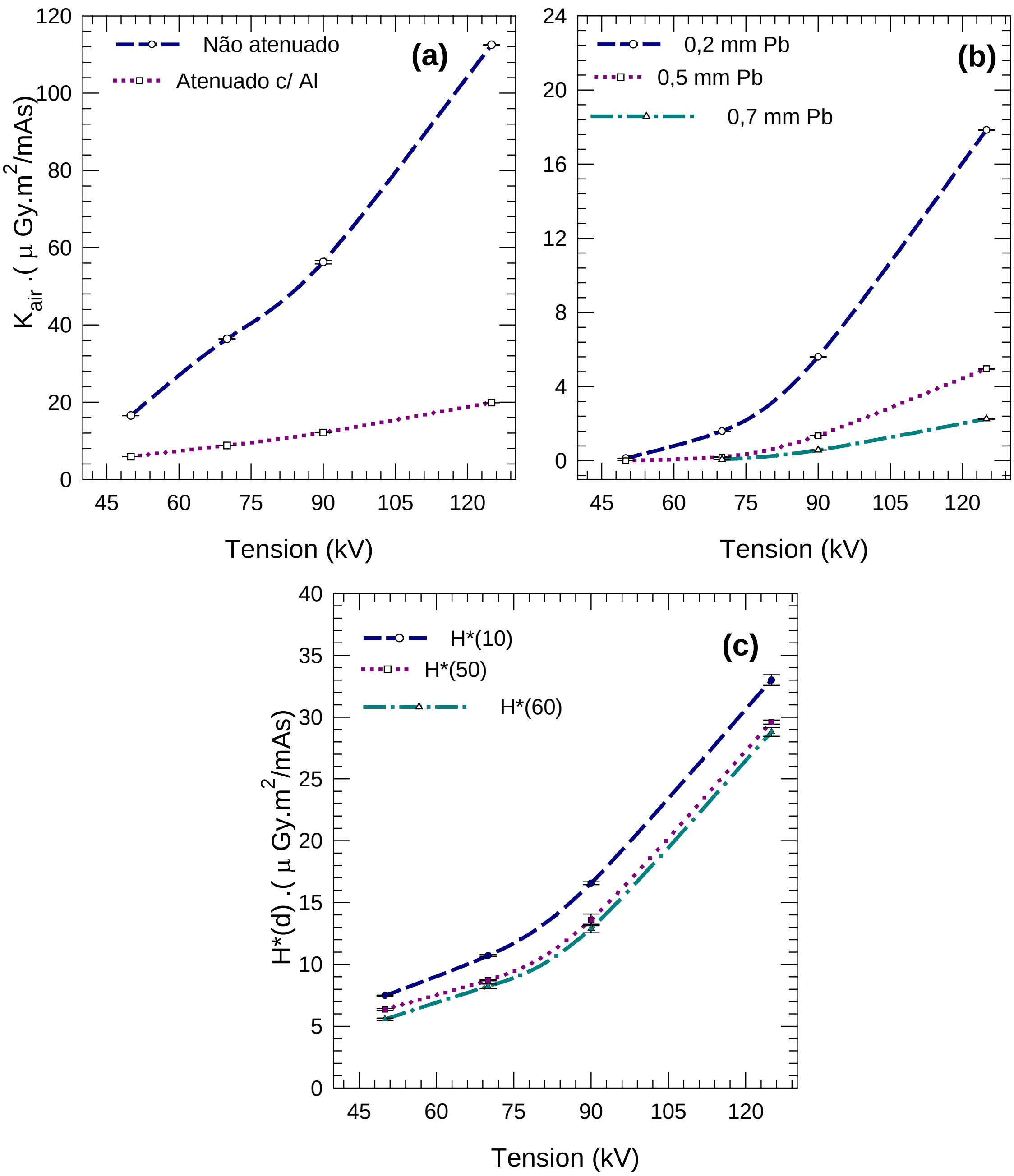

FIG. 1. *X-ray output in terms of kerma in the air measured in an interval from 50 to 125 kV for unattenuated and attenuated qualities with (a) Al and (b) Pb. X-ray output in terms of H*(d) for attenuated qualities.*

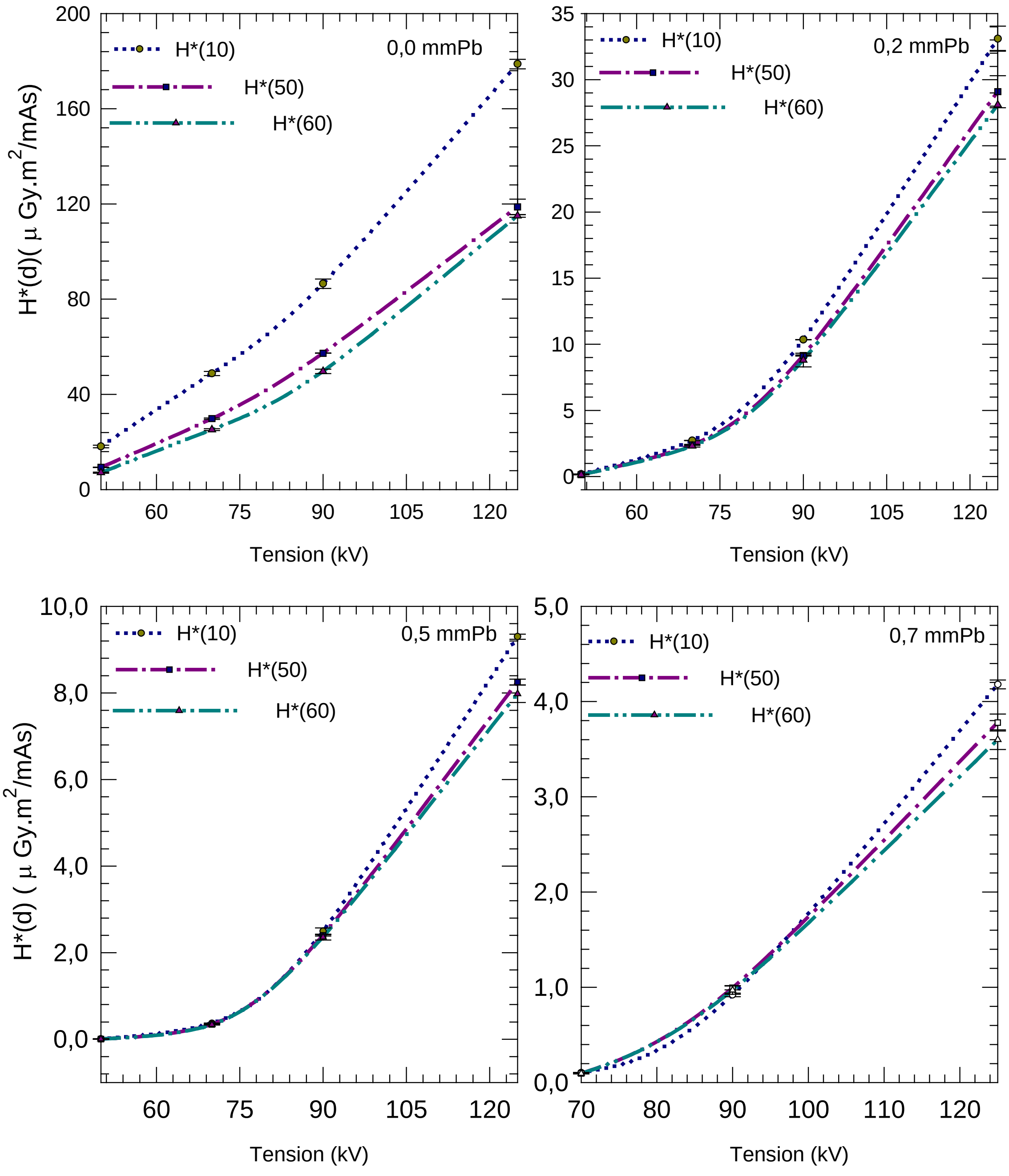

FIG. 2*. X-ray output in terms of H*(d) at 10, 50 and 60 mm depth in the PMMA sphere for 0.0; 0.2; 0.5 and 0.7 mm Pb.*

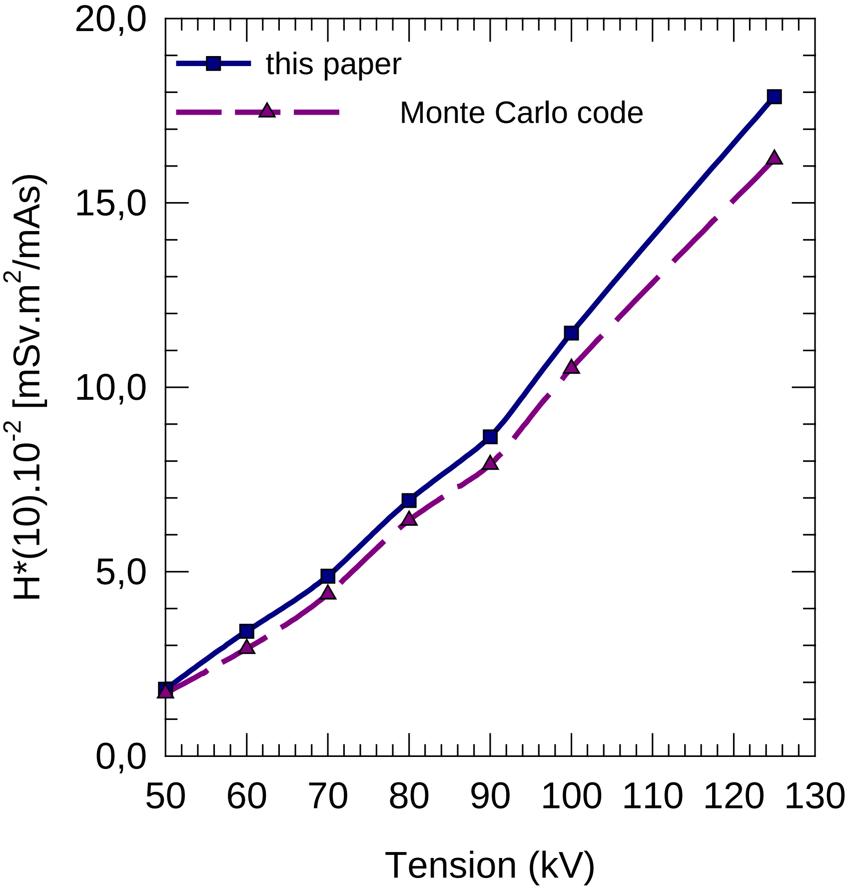

FIG. 3. *X-ray output in terms of H*(d) to unattenuated beam measured in this paper and calculated using a Monte Carlo code [9].*

Conclusion

According to what was shown and discussed here, it was concluded that determined x-ray outputs can be applied to calibration in ambient monitoring in the area of work in x-ray diagnostic installations. It can also be used the determined values at 60 mm of depth in the PMMA sphere that are the ones that better estimates the effective dose in this interval of energy.

REFERENCES

[1] MATTSSON, S. ; ALMÉN, A. Pratical Impact of the Evolution and Changes of ICRP Recommendations on Radiological Protection in Medicine**. *Radiat. Prot. Dosim.,*** v. 57, n. (1-4), p. 79 - 84, 1995.

[2]- Recommendations of the ICRP, Publication N°. 60, Annals of the **ICRP 21** N°. 1-3. INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. (ICRP), New York, USA. Pergamon, 1991.

[3] INTERNATIONAL COMMISSION ON RADIOLOGICAL UNITS AND MEASUREMENTS - (ICRU). Determination of Dose Equivalents Resulting from External Radiation Sources. Report 39, 7910 Woodmont Ave., Bethesda, MD 20814, USA, 1985.

[4] INTERNATIONAL ELECTROTECHNICAL COMMISSION - (IEC). Medical Diagnostic X-ray Equipment Radiation Conditions for use in the Determination of Characteristics. CEI/IEC 1267, 1994,

[5] Nogueira, M. S. *Determinação dos Fatores de Kerma no ar e de Fluencia para o Equivalente de dose Ambienatal para raios X Gerados no Intervalo de 50 kVp a 125 kVp.* University of SP/Brazil (1997). PHD Thesis (in Portuguese).

[6] INTERNATIONAL COMMISSION ON RADIOLOGICAL UNITS AND MEASUREMENTS - (ICRU). Measurements of Dose Equivalents from External Photon and Eletron Radiation, Report 47, 7910 Woodmont Ave., Bethesda, MD 20814, USA, 1992.

[7] INTERNATIONAL COMMISSION ON RADIOLOGICAL UNITS AND MEASUREMENTS - (ICRU). Quantities and Units in Radiation Protection Dosimetry. Report 51, 7910 Woodmont Ave., Bethesda, MD 20814, USA, 1993.

[8] Nogueira, M. S.; Campos, L. L. ; Mota, H. C. *Determination of Conversion Coefficients Between air Kerma or Photon Fluence and Ambient Dose Equivalent for Diagnostic X ray Beams.* Radia. Prot. Dos. **81** (2), 123-132 (1999).

[9] Peixoto, J. E. *Determinação dos Fatores de Atenuação e dos Coeficientes de Conversão em Termos do Equivalente de Dose Ambiental e da Dose Efetiva para Raios-X Gerados na Faixa de 50 a 150 kVp*. PhD Thesis (in Portuguese). Federal university of RJ/Brazil (1995).