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EVALUATION OF WORKLOAD WEIGHED TRANSMISSION CURVES OF COMMERCIAL SHIELDING MATERIALS USED IN DIAGNOSTIC ROOMS

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ABSTRACT

Evaluation of beam attenuation properties of shielding materials used in diagnostic rooms was obtained following the method proposed by Archer et. Al (Med. Phys. 21 (9), 1994). These attenuation properties were measured by using a constant potential X-ray machine operated in voltages from 60 to 150 kV. Moreover, workload distributions (Simpkin, Med. Phys. 23(4) 1996) of typical diagnostic rooms were obtained. The workload weighed transmission curves were obtained considering the different shielding material manufacturer and workload spectrum. This method published in NCRP 147 presents a strong dependence on quantities workload distribution and transmission through the shielding materials. The correct consideration of this combination allows the optimized determination of the shielding material thickness needed for protecting the environment.

1. INTRODUCTION

Several working programs were conducted during the last years on revisiting the previous methodologies for shielding design of diagnostic imaging facilities[1-4]. These works resulted on the publication of recommendations from the National Council on Radiation Protection (NCRP) in US in 2005[5]. This publication included results of attenuation properties of several materials typically used for radiation shielding purpose in US[6]. However, these attenuation properties can not be directly used on performing shielding calculations when using Brazilian structural materials. Preliminary studies of the behavior of local shielding materials have been conducted in the last years[7-10].
A strong motivation of the present study is related to the fact that the most typically shielding material used in Brazil are barite concrete, which was not evaluated by Archer et. al.[6]. Other important concept is the workload spectra introduced by Simpkin[2]. This quantity allows taking into account the typical charge of use of diagnostic rooms. Simpkin evaluated the workload spectra of different imaging modalities typically present in North-American hospitals. Similarly to the attenuation properties of the materials, the

workload spectra evaluated by Simpkin can not be directly adopted in shielding calculations for Brazilian facilities, since the behavior of the imaging technicians, the x-ray devices technology and the biotype of the patient are different from the US.
However, the attenuation properties available in the literature can not be directly used for shielding calculations when using Brazilian structural materials.
Preliminary studies of the behavior of local shielding materials have been conducted in the last years[8-10]. The present work was motivated by the need of make available transmission curves considering local shielding materials (barite concrete) and workload spectra typically found in Brazilian facilities. The present work presents an evaluation of attenuation properties of typical Brazilian shielding materials (Barite Concrete) used in diagnostic rooms from transmission measurements considering the local workload distribution. The results of measured attenuation properties of local barite concrete were combined to a set of workload spectra obtained in Brazilian hospitals.

2. METHOD AND MATERIALS

Broad beam attenuation properties of three shielding materials were obtained following the method proposed by Archer et. al.[6], by measuring the air-kerma transmitted trough the samples. These attenuation properties were measured by using a constant potential X-ray machine Philips MGC 40 with a Philips tungsten anode with beryllium window x-ray tube MCN 323. This system was operated at voltages from 60 to 150 kV by using an additional filtration of 3 mm Al which corresponded to a RQR 8 radiation quality[11]. The primary and transmitted air-kerma from different material thicknesses were measured by using a Radcal 10x5-6 ion chamber conected to a Radcal 9015 electrometer. Figure 1 shows the experimental setup used for obtaining the broad beam transmission data.
The evaluated samples are commercially used barite concretes which manufacture's names are omitted in this paper. The basic elements of these samples are the Barium (6-40%) and the Calcium (16-32%). Differences in the composition of the samples are presented in ref 12 The transmission data were introduced into a routine prepared in the Origin 6.0 software (Microcal, inc.) which calculates the Archer parameters by using a non-linear least square fit.
Moreover, workload spectra[2] of typical diagnostic rooms were obtained by observing 1060 patients, considering 2246 expositions, in five different hospitals. These data were combined following the method presented in NCRP 147.
Finally, the results of applying Archer's Model were combined to the measured workload spectra in order to obtaining weighed transmission curves of the studied samples. The equation used for this operation was the following:

$$\frac{I_W(x)}{I_W(0)} = \sum_V \frac{I(x,V)}{I(0,V)} \times W(V) = \sum_V \left[\left(1 + \frac{\beta(V)}{\alpha(V)} \right) e^{\alpha(V)\gamma(V)x} - \frac{\beta(V)}{\alpha(V)} \right]^{-\frac{1}{\gamma(V)}} \times W(V)$$

Where W(V) is the function describing the workload spectra, V is the voltage of the x-ray tube in kV and α(V), β(V) and γ(V) the Archer's parameters obtained by applying a non-linear least square method.

Figure 1 – Experimental setup used for obtaining the broad beam transmission data

3. RESULTS

Workload spectra of conventional X-ray rooms resulted from observing 1060 patients in five different hospitals is presented in Figure 2.
Figure 3 presents the transmission curves obtained by applying the Archer's equation[6] to the experimental points. The Archer parameters were obtained by using the non-linear least square method to the Archer's equation.
The workload weighed transmission curves were obtained considering the different workload spectra and shielding material manufacturer. Examples of these weighed transmission curves are presented in Figure 4.

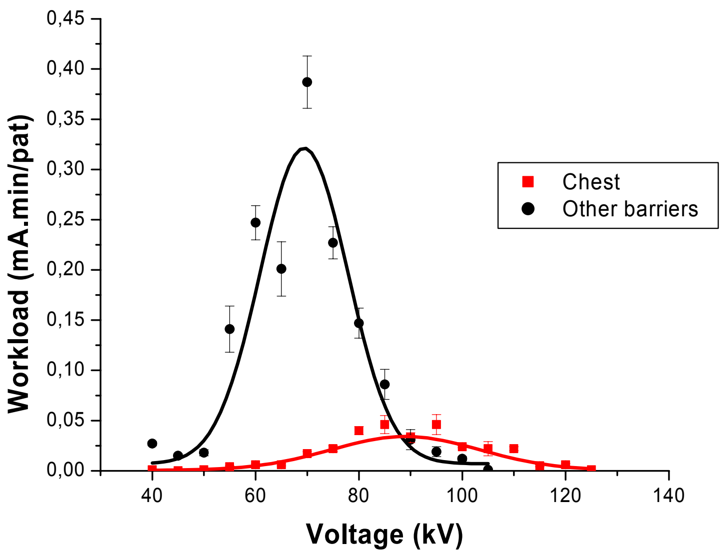

Figure 2 – Workload spectra measured and corresponding Gaussian fits for chest wall, other barriers and total.

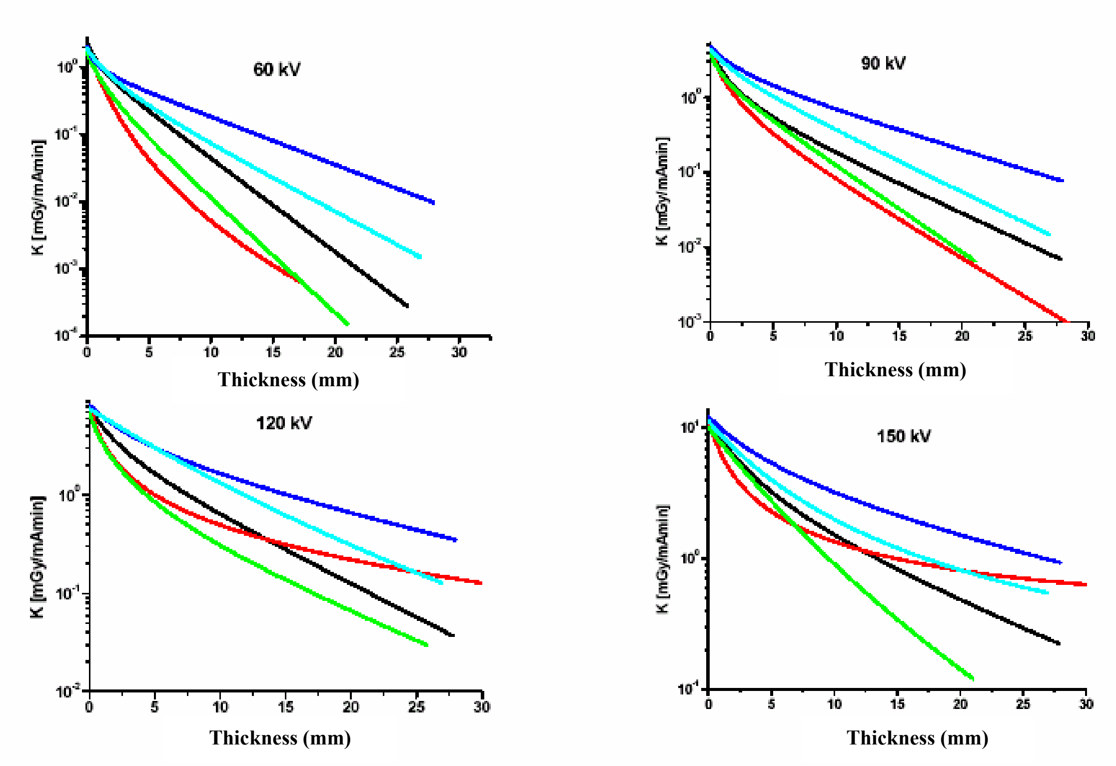

Figure 3 – Transmission curves obtained by applying the non-linear least square method to the Archer's equation by using the experimental data obtained using 60, 90, 120 and 150 kV for five different barite concrete samples.

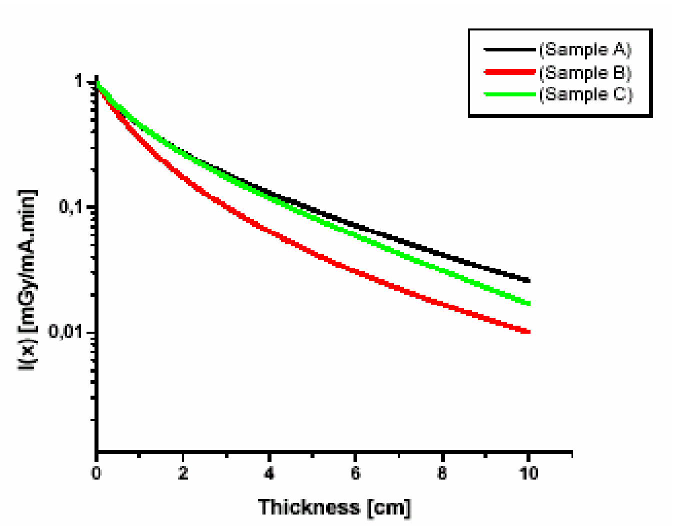

Figure 4 – Examples of weighted attenuation curves for three samples of Brazilian barite concrete taking into account the total workload into the eq. (1).

4. CONCLUSIONS

Results show a strong dependence on the quantities workload distribution and transmission through the shielding materials. Considering the 120 kV transmission curve presented in Figure 3, and for a transmission factor of 0.01, the thicknesses of material required for shielding a conventional radiation room to primary radiation ranges 19 to 39cm of barite concrete, depending on the manufacturer. This range of thicknesses decreases to 10 to 14.5 cm if the workload spectra are considered. This result can be obtained by observing the Figure 4. The results show that the sample B presented the better performance regarding attenuation properties, followed by sample C and sample A. These comparative results shows the importance of taking into account the workload distribution in order performs correct the shielding calculations for diagnostic rooms. Local evaluations are needed to adapt this method to the shielding materials and the local workload distributions. The accurate consideration of this combination allows the optimized determination of the shielding material thickness needed for complying with the local radiation protection requirements.

REFERENCES

[1] ARCHER, B.R. History of the Shielding of Diagnostic X-ray Facilities. ***Health Physics***, v.69, n. 5, p. 750-758, 1995.

[2] SIMPKIN, D. Evaluation of NCRP Report No. 49 Assumptions on Workloads and Use Factors in Diagnostic Radiology Facilities. ***Medical Physics***, v. 23, n.4, p.577-584, 1996.

[3] SIMPKIN, D.J.; DIXON, R.L. Secondary Shielding Barriers for Diagnostic X-ray Facilities: Scatter and Leakage Revisited. ***Health Physics***, v.74, n. 3, p. 350-365, 1998.

[4] DIXON, R.L.; SIMPKIN, D.J. Primary Shielding Barriers for Diagnostic X-Ray Facilities: A New Model. ***Health Physics***, n.74, v.2, p. 181-189, 1998.

[5] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Structural Shielding Design for Medical X-ray Imaging Facilities. NCRP Publications, Bethesda, MD, 2004 (NCRP Report 147).

[6] ARCHER, B.R.; FEWELL, T.R.; CONWAY,B.J.; QUINN,P.W. Attenuation Properties of Diagnostic X-ray Shielding Materials. ***Medical Physics***, v. 21, n.9, p.1499 -1507, 1994.

[7] COSTA, P.R. – Modelo para determinação de espessuras de barreiras protetoras em salas para radiologia diagnóstica. Tese de Doutorado apresentada na Universidade de São Paulo/IPEN-CNEN-SP na área de Tecnologia Nuclear, São Paulo, 1999

[8] BARROS, F.S. – Determinação das propriedades de atenuação de tijolos cerâmicos maciços e argamassas baritadas para sua utilização como barreira de proteção em salas de radiodiagnóstico. Dissertação de mestrado apresentada no CEFET-PR, 2001

[9] DE PAULA, F.T.,NERSISSIAN, D. Y., COSTA, P. R. - Estudo das propriedades de Atenuação de Argamassas Baritadas utilizadas em Proteção Radiológica. XI Cesso Brasileiro de Física Médica, Ribeirão Preto, 2006.

[10] FRIMAIO, A.; COSTA, P.R.; VENDERLINDE, F.V.F.;CAMPOS, L.L. - Development of a ceramic compound for coating the wallsof image diagnosis centres for dose reduction of medical team. ***Int.J. Low Radiation***, v. 3, n 9, p. 355-363, 2006.

[11] INTERNATIONAL ELECTROTECHNICAL COMMISSION - Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristics. IEC Publications, Geneva, Switzerland, 2005 (IEC 61267).

[12] COSTA, P.R.; BRAGA, N.A. - Workload Weighed Transmission Curves of Brazilian Shielding Materials: computer simulations. Paper submitted to the *International Nuclear Atlantic Conference - INAC 2007Santos, SP, Brazil, September 29 to October 5,* 2007.