Comparative evaluation of three barite concretes against radiation from different workload spectra

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Abstract. A strong motivation of the present study is related to the fact that the most typically shielding material used in Brazil is barite concrete. This paper provides an evaluation of attenuation properties of three barite concretes used for shielding of diagnostic imaging rooms. These attenuation properties were combined to the workload spectra typically presented in Brazilian facilities. A comparative evaluation of three barite concrete manufactures was obtained by the results of this combination.

KEYWORDS: shielding materials; workload spectra; X-rays.

1. Introduction

The present work presents a comparative evaluation of attenuation properties of typical Brazilian shielding materials (Barite Concrete) used in diagnostic rooms from transmission measurements considering local workload distributions.
Archer et. al.[1] evaluated typically materials used in diagnostic rooms in US. This and other works were conducted revising the previous methodologies for shielding of diagnostic imaging facilities[2-5], and resulted on the publication of recommendation from the National Council on Radiation Protection (NCRP) in US in 2005[6].
The present study is related to the fact that the most typically shielding material used in Brazil is barite concrete, which was not evaluated by Archer. Preliminary studies of the behavior of local shielding materials have been conducted in the last years[7-10].
Other important concept is the workload spectra introduced by Simpkin[3]. 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.
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 results of measured attenuation properties of local barite concrete were combined to a set of workload spectra obtained in Brazilian hospitals and was realized a comparative evaluation of three different barite concrete manufactures.

2. Materials and Method

2.1 Workload spectra

Workload spectra allow taking into account the typical charge of use of diagnostic rooms. In the present work, it was evaluated workload spectra typically found in Brazilian facilities. Workload data was determined and normalized per patient for each installation. The data were fitted by a Gaussian model, using Origin 6.0 software (Microcal, inc.). Workload spectra of general diagnostic rooms were obtained by observing 1060 patients, considering 2246 expositions, in six different hospitals.

2.2 Attenuation properties of shielding materials

Broad beam attenuation properties of three shielding materials were obtained following the method proposed by Archer et. al.[1]. 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 3mm Al which corresponded to a RQR 8 radiation quality. The primary and transmitted radiation from different material thicknesses were measured by using a Radcal 10x5-6 ion chamber connected to a Radcal 9015 electrometer.
These 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.

2.3 Workload weighed transmission curves

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 (1) was used for this operation.

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

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.

3. Results

Workload spectra of conventional X-ray rooms resulted from observing 1060 patients in five different hospitals is presented in Figure 1.
Table 1 presents total data of patients, number of exposures, workload and workload error, and average data of exposures per patients, divided in chest and other barriers. Table 2 presents total data divided per hospital.
Figure 2 presents the transmission curves obtained by applying the Archer's equation to the experimental points. The Archer parameters were obtained by using the non-linear least square method to the Archer's equation, and are presented in Table 3.
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 3.

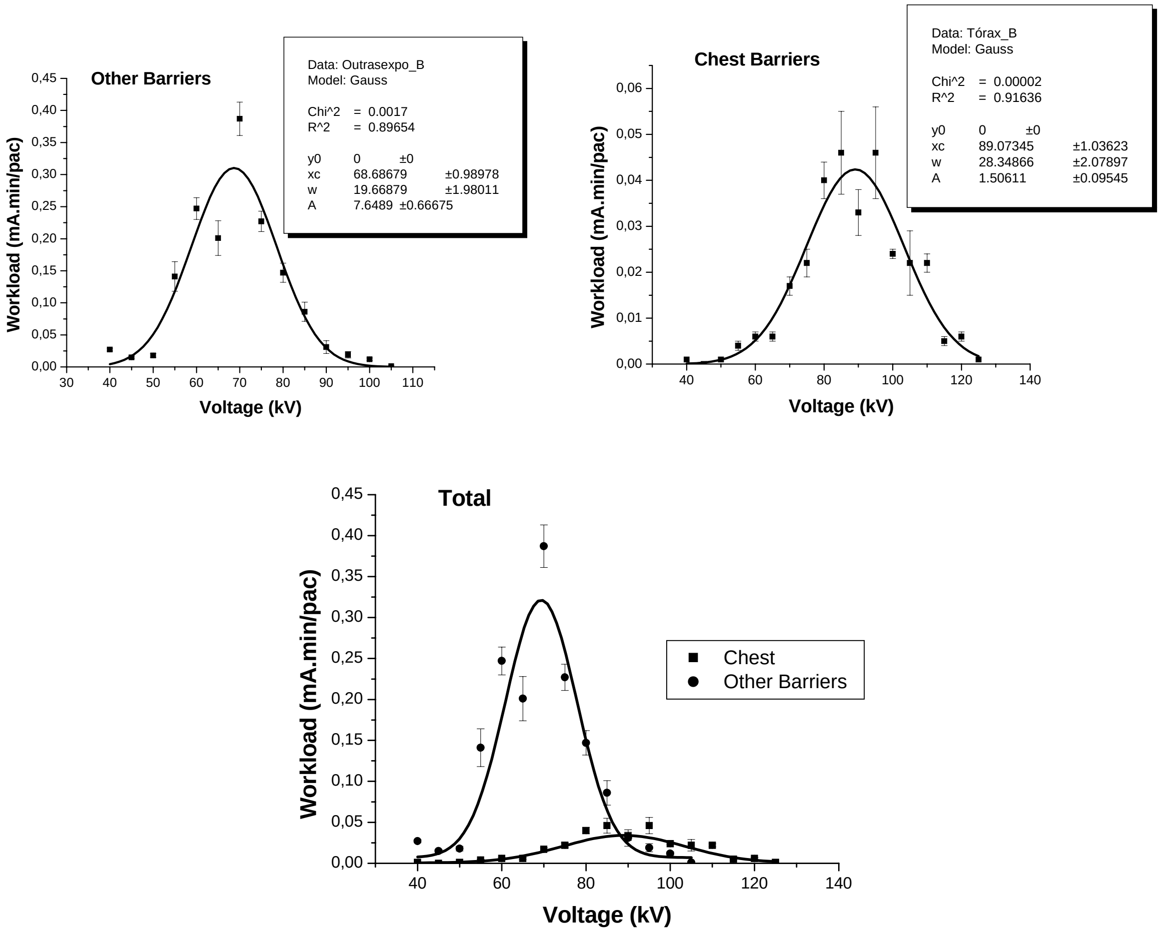

Figure 1. Workload spectra measured and corresponding Gaussian fits for chest wall and other barriers.

Table 1. Total data for chest wall and other barriers.

Exam	N° patients (N_p)	N° Exposures (n)	Exposures per patient (n/N_p)	Workload (W)	Workload Error (σ_W)
Chest	603	1127	1,869	0,302	0,017
Other barriers	453	1116	2,464	1,559	0,055

Table 2. Total data in each hospital.

Hospital	N° patients (N_p)	N° Exposures (n)	Exposures per patient (n/N_p)	Workload (W)	Workload Error (σ_W)
A	70	135	1,929	1,370	0,116
B	46	99	2,152	1,305	0,198
C	81	148	1,827	1,456	0,118
D	314	602	1,929	0,532	0,024
E	326	789	2,420	1,055	0,064
F	223	473	2,121	0,573	0,029
Total	*1060*	*2246*	*2,119*	*0,722*	*0,028*

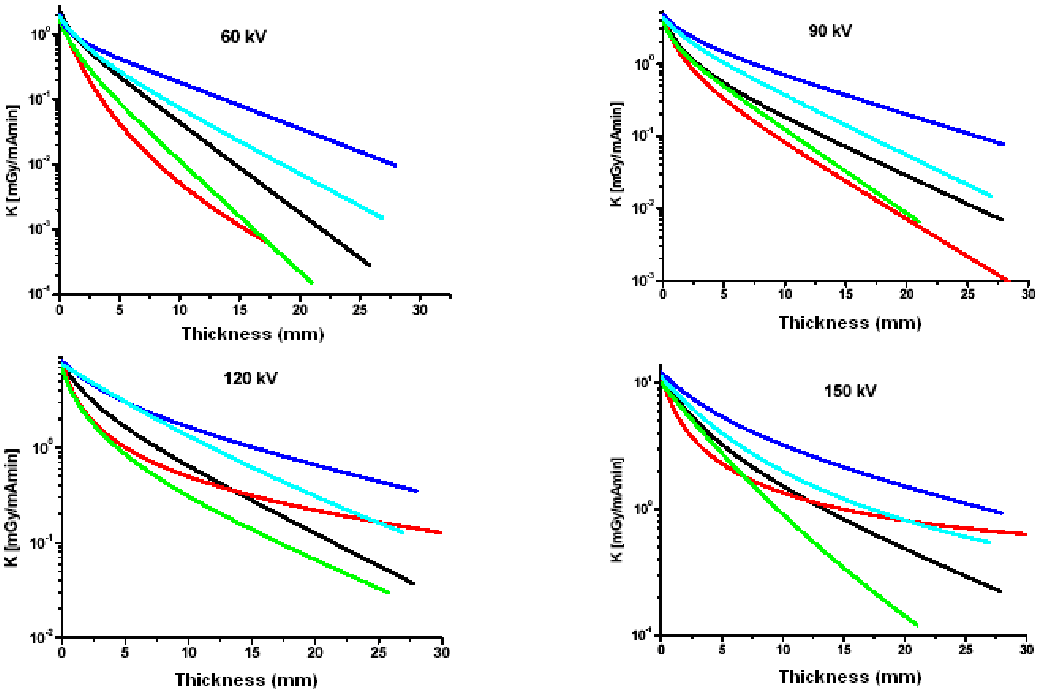

Figure 2. Transmission curves obtained by applying the non-linear least square method to the Archer's equation by using the experimental data obtained different voltajes.

Table 3. The Archer parameters

	I_0			α		β			γ	
Fabricante	A_{I0}	B_{I0}	C_{I0}	A_α	B_α	A_β	B_β	C_β	A_γ	B_γ
I	-0.321	0.008	$9.40X10^{-5}$	4.049	-0.018	4.293	-0.037	$1.42X10^{-4}$	0.172	$4.89X10^{-3}$
II	0.369	0.010	$1.04X10^{-4}$	0.642	-0.002	18.252	-0.209	$7.09X10^{-4}$	0.420	$4.74X10^{-3}$
III	-0.371	0.009	$1.08X10^{-4}$	0.908	-0.006	51.207	-0.464	$1.40X10^{-3}$	0.305	$8.89X10^{-3}$
IV	-0.403	0.010	$1.12X10^{-4}$	0.706	-0.004	11.616	-0.072	$2.90X10^{-4}$	0.118	$1.67X10^{-2}$

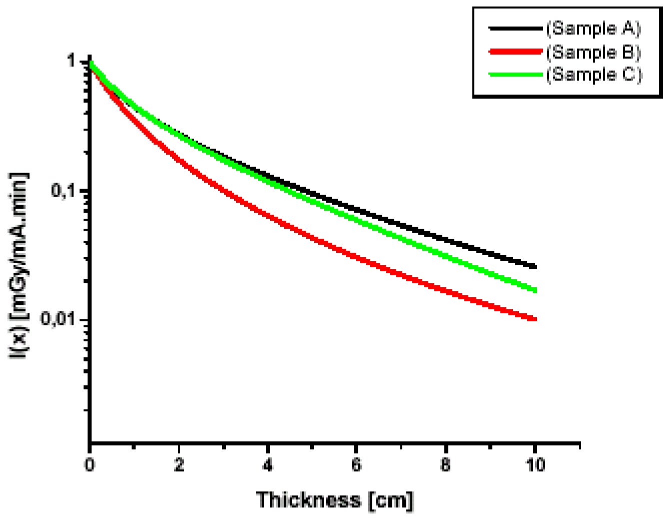

Figure 3. Weighted attenuation curves for three samples of Brazilian barite concretes taking into account the total workload spectra into the eq. (1).

4. Conclusion

Comparative results regarding data from the observed local workloads for the different shielding materials commercially available shows thickness variations of 0.50cm, 1.07cm and 1.88cm for chest workload, and 0.31cm, 0.75cm and 1.25cm for other exposures workload, considering a transmission factor of 0.1. Moreover, for the same transmission factor, but using the workload spectra published by Simpkin, the thickness variation founded was 0.57 cm, 1.13cm and 2,07 cm for chest workload and 0.354cm, 0.825cm and 1.40cm for other exposures workload.

The results show a strong dependence on the kind of the shielding material regarding the thickness required for attenuating the same factor (0.1), instead all evaluated materials been commercially referred as barite concretes. Moreover, it was found variations from 5-11% and 9-11% when comparing the results considering the local and published workloads. For the evaluated local workloads the barite thickness needed for protecting an area were found lower then using NCRP 147 workloads. The correct consideration of this combination allows the optimized determination of the shielding material thickness needed for protecting the environment.

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