

SPECTRA TRANSMITTED BY MORTAR BARITE IN X-RAY QUALITIES APPLIED IN DIAGNOSTIC RADIOLOGY AS SHIELDING

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Abstract: Concrete which contains water, cement and aggregate, is widely used in building construction such as medical hospitals. The CdZnTe spectrometry system was used to acquire the transmitted spectra in the RQR qualities and the stripping procedure was performed by taking into account both the contributions of efficiency and x-ray escape fraction, experimentally determined. The samples were prepared in rectangular plate format with dimensions of (5 x 5) cm with thicknesses varying from 0.2cm to 2cm and exposed to x-ray beams generated. The HVL and the mean energy in this energy range was determined.

Keywords: shielding; barite mortar; x-ray spectra; concrete; ambient dose equivalent

1. INTRODUCTION

Adequacy of the shielding, walls as well as equipment must be monitored by means of radiometric assessment. The equipment must be kept under adequate technical conditions and a quality control programme must be implemented. Therefore, aiming at protecting the premises and people against ionising radiation in radioactive facilities, the use of shielding materials is being studied by various researchers with a must-be-implemented objective to determine the curves of attenuation of the ionising radiations. Amongst the materials used as protection barriers, are lead, concrete and iron [1,2].

Relevant studies on the subject of barrier calculation in x-ray facilities were employed to consolidate the methodology of primary and secondary barriers proposed by the National

Council on Radiation Protection (NCRP) in 2004, expressed in NCRP Report 147 [3]. The acknowledgement of the characteristics of attenuation of barite is fundamental, from the radioprotection point of view to the viabilisation, to design and execution of projects of ionizing radiation shielding in radioactive facilities. The main aim of this work is to characterise the barite mortars found in different regions of Brazil by measuring the x-ray spectra emerging from the x-ray radiation beams attenuated by the various samples generated in diagnostic radiology qualities, so that the operational quantities equivalent of ambient doses (H*) can be determined for comparison with the effective dose.

2. Experimental

This study aims at characterising samples of purple, white and cream barite occurring in different parts of Brazil, which are used in radioprotection such as x-ray shielding materials.

These materials are used in radioactive facilities as X radiation shielding for they present advantages such as: low cost, high efficiency in shielding and are easy to handle besides being widely available in the local market. Table 1 depicts the materials used in this research, as well as the state of the country where each of them were found. Enhancing the fact that, of all materials studied in this work, the purple barite from the state of Bahia is the hardest to mine.

Table 1 - Materials used as X radiation shielding.

<i>Shielding Materials</i>	<i>Origin</i>
White barite mortar	State of Paraíba
Cream barite mortar	State of São Paulo
Purple barite mortar	State of Bahia

In order to perform the measurements of x-ray spectra, the incident beams as well as the ones transmitted by samples, the following spectrometry was applied: Detection system made up of a CdTe detector connected to a pre-amplifier made by Amptec model XR -100T-CdTe, as described in Table 2.

The measurements of the spectra were checked with the detector placed at 340 cm from the focal point, and the barite mortar plates or a set of them were positioned at 50 cm from the focal point.

The positioning of the detector was done by using the calibration setup with a beam collimator, and its alignment with the central ray of the radiation beam was done by employing laser convergent. Reference x-ray qualities were used as recommended by IEC 61267[4] (RQR – level of diagnosis guidelines), as presented in Table 3.

Table 2 – Specifications of the Amptek CdTe detector.

Parameter	Specification
Detector	CdTe model XR-100T-CdTe Nominal operation voltage: 400 V
Detection characteristics	Resolution (keV): 0.53 to 14.4 keV 0.85 to 122 keV
Geometric Characteristics of the crystal	Area: 3x3 mm ² Thickness: 1 mm
Characteristics of the electronic system connected to the detector to collect data	Shaping time: 3 μs Gain: 4,5 RTD: on

Table 3 – Characteristics of RQR qualities implanted at CRCN/CNEN.

Qualities	Voltage (kV)	Additional filtration (mm Al)	1° HVL (mm Al)	2° HVL (mm Al)
RQR4	60	2.90	2.19	2.6
RQR6	80	3.05	3.01	4.36
RQR9	120	3.90	5.00	7.40
RQR10	150	4.40	6.57	9.13

After the measurements of the radiation spectra, some corrections are necessary to provide various interactions of radiation with materials that make up the detector. These corrections are due to materials that may be attenuating the radiation and the determination of this energy influences the mean energy. The corrections to primary x-rays transmission, secondary x-rays escape, K-fluorescent x-rays and Compton-scattered x-rays from the attenuation due to materials of the detector are usually carried out using the stripping method [5] that was also applied in this work.

3. Results and Discussion

3.1. Calibration of the spectrometer

The XR-100T-CdTe detector was calibrated for correct measurements of spectra by using standard sources of radiation ²⁴¹Am, ¹⁰⁹Cd and ¹³³Ba. By considering the results of the spectra

achieved for each source in this study and the value of their activities, it was possible to calculate the efficiency of the detector CdTe in function of the energy of the photopeak. The results of the values calculated by the Monte Carlo method, as well as those obtained experimentally. Figure 1 shows a good agreement between the average results measured and simulated by Monte Carlo. Three steps observed in the respective figure can be associated to the “escapes-k” of Cadmium (Cd) and Tellurium (Te) between energies of 20 and 30 keV [6]. In the corrected spectra these degrees are partially eliminated.

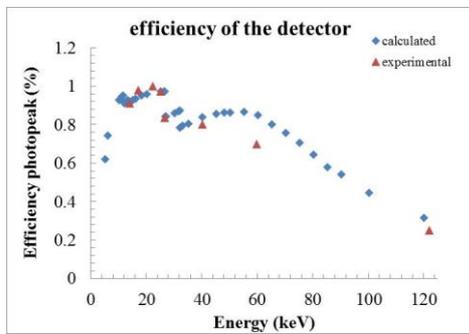


Figure 1– Efficiency photopeak obtained through ^{241}Am , ^{133}Ba , ^{109}Cd and ^{152}Eu sources.

3.1. Incident and transmitted spectra transmitted by barite matters

Figure 2 presents the comparisons between the non-corrected spectra (distribution and pulse height) and the corrected ones (photon spectra) which were obtained according to RQR radiation qualities recommended in the IEC guidelines.

The difference between the measured spectra and corrected spectra is visible, especially in the region of low energy of the measured spectra. Furthermore, this spectra presents depressions or “dips” at 27keV and 32keV, being more noticeable in the low energy spectra. These dips were also related in the study by Miyajima [6], where the author states they are related to the fraction of escape of the K layer of the Cd and Te, respectively. In the corrected spectrum these dips are partially corrected, thus having their intensity reduced as a result (Fig. 3).

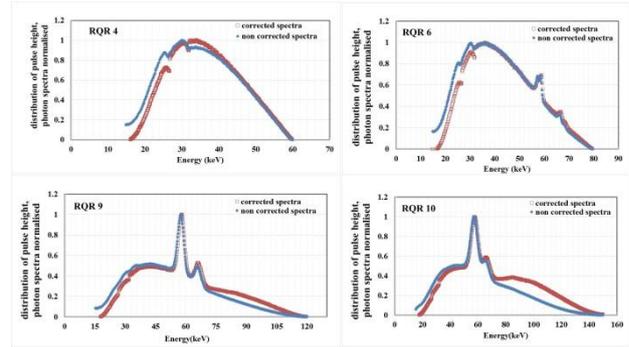


Figure 2 – Pulse spectra and incident photon spectra with and without correction.

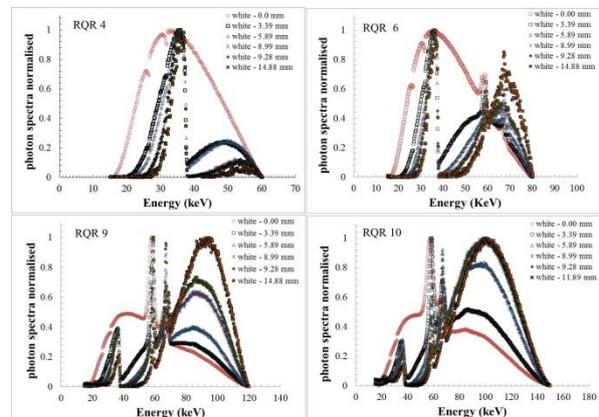


Figure 3 – Transmitted x-ray spectra- in qualities RQR4, RQR6, RQR9 and RQR10 for different barite mortars.

In Figure 3, the spectra transmitted by white barite plates which were measured using the IEC qualities aforementioned are represented. These spectra were normalised for the same maximum photon area. An analysis of Figure 3 shows that the primary spectra are highly modified as it crosses the barite thickness. A very important aspect of these spectra is the peak of absorption of Barium, around 40KeV, which cuts the photons above this energy deeply. In lower energy spectra which is the case of RQR4, this situation is well noticeable.

The modification of the primary spectrum, when crossing the thickness of the barite will have a great impact on the quantities, which depend on the photon spectra, such as $H^*(d)$ and the effective dose and what represents an important aspect in metrology, mainly in area monitoring, where it is necessary to estimate the effective dose. Figure 4 presents the spectra transmitted for each type of barite mortar,

according with the RQR qualities used. It can be observed that the cream barite presents a better shielding efficiency in this energy range for diagnosis x-ray, followed by the white barite. This difference is better observed in qualities RQR4 and RQR6 for they are of lower energies.

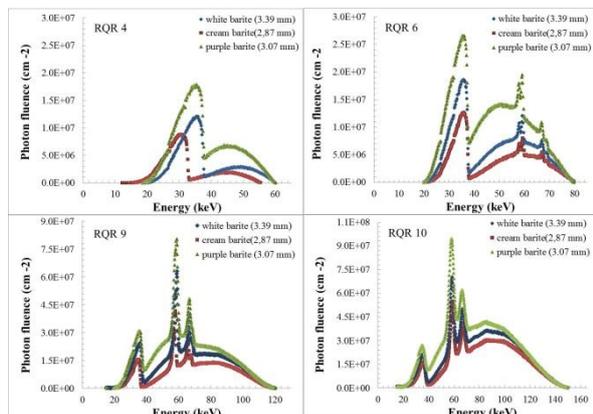


Figure 4 – spectra transmitted for each type of barite mortar in qualities RQR4, RQR6, RQR9 and RQR10.

The atomic composition of these materials may vary according to different manufacturers and may result in a variation in the attenuation of the radiation in function of energy and thickness, thus presenting a modification in the behaviour of the transmission spectrum (Fig. 6).

4. CONCLUSION

The characteristics of attenuation of barite influence the transmission curves in the range of energy of diagnostic radiology. Also, it was demonstrated that the atomic composition of the barite influences the transmission curves of the x-rays, hence showing the importance of atomic determination of these materials. The results achieved in this research made it possible to meet the respective dimensioning of these barriers with precision and safety, when designing shielding

using the studied materials as protection barriers against x-rays, thus optimising the cost of radiology protection.

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