Mass attenuation coefficients of x-rays in ISO quality concrete in barite of different regions of Brazil

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1.INTRODUCTION

The probability of a photon interacting in a particular way with a given material, per unit path length, is usually called the linear attenuation coefficient (μ), and it is of great importance in radiation shielding. Linear attenuation coefficients, however, depend on the density (ρ) of the shielding material. The density does not have an unique value but depends on the physical state of the material, for example, in the case of concrete, on its moisture content. To obviate the effects of variations in the density of the material, the linear attenuation coefficient is, for reference purposes, expressed as a mass attenuation coefficient (μ/ρ) which is the linear attenuation coefficient per unit mass of the material. For shielding materials consisting of chemical compounds or homogeneous mixtures, the atomic cross-section in barn/atom was computed from the μ/ρ using the following relation:

$$\mu / \rho = \sum w_i (\mu / \rho)_i$$

In the present work, the total mass attenuation coefficient (μ/ρ) have been calculated using the XCOM program. The XCOM program has a database cross-section for elements from Z=1 to 100, recently prepared to calculate the mass attenuation coefficient for elements, compound or mixture, at energies from 1 keV up to 100 GeV.

2.MATERIALS AND METHODS

Plates of barite concrete with different thickness were fabricated in order to determining their mass attenuation coefficients at different energies. The plates were irradiated with ISO X-ray beams (W60, W80, W110 and W150), generated by Pantak HF320 X-ray equipment, at the CRCN laboratory. The samples were collected from the different regions of the Brazil, from the states of Bahia, Piauí and Minas Gerais. In order to obtain data for the attenuation curves, 20 x 20 cm^2 barite slabs with different thicknesses (1 to 20 cm) were prepared. The experimental procedure in this work was validated by comparison between the experimental measurements of mass attenuation coefficients and the coefficients determined by the same atomic composition, using the XCOM tools. The samples composition was performed by X-ray Diffraction Analysis (XRD) at the CDTN laboratory.

3.RESULTS AND DISCUSSIONS

The mass attenuation coefficients of barite concrete have been measured using X-ray attenuation for different thicknesses of barite concrete in ISO qualities beams. The barite is utilized as X-ray and gamma radiation shielding and it is found in different regions of Brazil. The barite utilized in this study was obtained in southeastern and northeast Brazil. The percentage composition of barite concrete is given in Table 1. The Figure 1 shows the mass attenuation coefficients found in this study. The coefficients were calculated taking into account the atomic composition of this barite concrete. The results were compared with literature data for others barite concretes. It was observed that the total mass attenuation coefficients (μ/ρ) sharply decreases with an increase in the photon energy for all mentioned concretes. In this energy region, the predominant interactions are the absorbed photons by Photoelectric Effect and the Compton Scattering. For example, if the X-ray beam interacts with an absorber with atomic number Z=20, the dominant interactions at energies from 0.01 up to 0.1 MeV and 0.1 up to 100 MeV are the Photoelectric Effect and the Compton Scattering, respectively. The total mass attenuation coefficients depend on the elemental composition and, consequently, on the concrete density.

Table 1 – Sample composition of Minas Gerais, in percentage, obtained by X-ray Diffraction Analysis (XRD)

Elemental composition (%)	
$BaSO_4$	46.2
SiO_2	34.8
CaO	10.0
Fe_2O_3	2.60
Al_2O_3	1.16
P_2O_5	0.650
K_2O	0.116
SrO	0.115
Nb_2O_5	0.026
ZrO_2	0.022
PbO	0.004

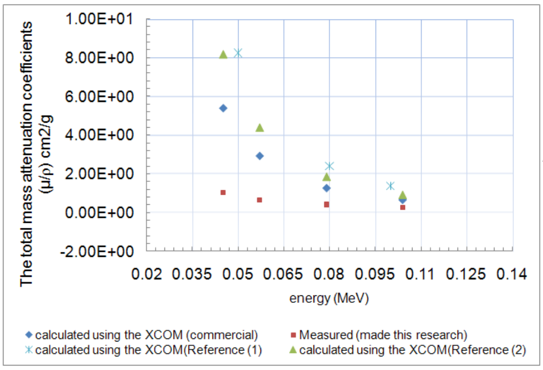

Figure 1 – Comparison between the results obtained in this study and the literature data

4.CONCLUSIONS

As can be seen from this figure that both calculated and measured data for the linear attenuation coefficients (μ) increase with the increasing materials' density, and the mass attenuation coefficient (μ/ρ) is constant as it is expected. It can be concluded that the photon attenuation coefficients depends on the photon energy and the materials' density is the main contribution to the photon attenuation coefficients, which is really important for radiation shielding.

5. REFERENCES

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MINISTÉRIO DO TRABALHO E EMPREGO FUNDACENTRO SEGURANÇA E SAÚDE DO TRABALHADOR

CAPES

CDTN CENTRO DE DESENVOLVIMENTO DA TECNOLOGIA NUCLEAR

CNEN Comissão Nacional de Energia Nuclear

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