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MASS ATTENUATION COEFFICIENTS OF X-RAYS IN DIFFERENT BARITE CONCRETE USED IN RADIATION PROTECTION AS SHIELDING AGAINST IONIZING RADIATION

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ABSTRACT

The attenuation coefficient depends on the incident photon energy and the nature of the materials. In order to minimize exposure to individuals. Barite concrete has been largely used as a shielding material in installations housing gamma radiation sources as well as X-ray generating equipment. This study was conducted to evaluate the efficacy of different mixtures of barite concrete for shielding in diagnostic X-ray rooms. The mass attenuation coefficient (μ/ρ). The mass attenuation coefficients have been measured by employing the CdTe detector model XR-100T. The distance between the source and the exposed surface of all samples was measured by SSD light indicator of machine which was 350 cm. The slope of the linear plot of the intensity transmitted versus specimen thickness would yield the attenuation coefficient. The mass attenuation coefficients (μ/ρ) were compared with the tabulations based upon the results of the XCOM program. The rectangular barite concrete blocks in different thicknesses from were used for the radiation attenuation test. The experimental values were compared with theoretical values WinXcom. The plots of the logarithm of transmitted intensity versus specimen thickness were linear for all the samples and the μ/ρ was obtained from the plots by linear regression over the 25%-2% transmission range, under good geometrical condition. There is a good agreement between theoretical and experimental values, within the 9%. In fact over the entire transmission range of 25-2% the experimental and theoretical values agree well for both the energies.

1. I. INTRODUCTION

The applications of radiation with X-ray appliances in medical and dental diagnosis are supervised by the sanitation department in both municipal and state levels, in accordance with rules established by the National Agency of Sanitary Supervision in Brazil - ANVISA. Moreover, The Ministry of Labour and Employment also inspects the workplaces, with the view to control occupational exposures.

Radiology protection starts by observing the norms and rules i.e. the norm nr. 453 of the Ministry of Health (MS, 1998). According with which, all physical infrastructure, as well as the way the equipments is placed, shielding and control areas, must be designed in function of occupation in the surroundings of the facilities. The walls and doors, must have their thickness well calculated as to assure protection of the public in general as well as staff occupationally exposed to ionizing exposures.

Amongst other materials used as shieldings are lead, concrete and steel (DOUGLAS, 1987; JAEGER et al., 1975; ALMEIDA JR, 2014). However, barite mortar, which is a material made of cement, sand, water, and barium sulphate has been widely used in radiology facilities to shield X-ray radiations for it presents aspects such as, high efficiency as attenuation materials, are easy to handle, wide availability in the domestic marketplace and low cost (JAEGER et al., 1975).

However, in practice, the dimensioning of the barite mortar and concrete used in building and plastering walls is determined by the principle of thickness equivalence in relation to concrete or lead. This procedure leads to an overestimated dimensioning, and significant errors might occur due to the difference in specific density between lead or concrete and barite, besides producing common overloads in facilities structures. Thus, the knowledge of the attenuation characteristics of the barite is fundamental, as far as radioprotection and viability is concerned. Elaboration and execution of projects for shielding ionising radiations in radioactive facilities is also uppermost.

According to the exponential decay constant, the coefficient of mass attenuation for narrow X-ray beams can be determined by using the following relation:

$$I = I_0 \exp[(\frac{\mu}{\rho})t] \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where: I_o and I are the intensities of the radiation beam with and without absorber, respectively. A variable “t” expresses the density of the material. E, the relation, μ/ρ the coefficient of mass attenuation for the material investigated.

According to Morabad et.al. (MORABAD, 2010), for a determined energy of the photon, the attenuation values can be obtained in function of the thickness of the material investigated, at a transmission range between 2% and 50%. MORABAD e KERUR (2010) measured the mass attenuation coefficient of leaves of Indian medicinal plant collected in different regions. For the determination of the experiment of mass attenuation coefficient, the authors used a ^{241}Am source, which produced X-rays in the range of 8 to 32 keV, using targets of Cu, Rb, Mo, Ag and Ba. According to the literature mentioned, the X-ray beams went first through a collimator, then hit the samples in the form of thin plates, until they reached a NAI(Ti) detector.

The coefficients μ/ρ were determined through the inclination of the line expressing the logarithm of the intensity transmitted in function of the thickness of the material assessed.

The main objective of the study was to characterize and determine the attenuation coefficients of the mortars made of barites found in different regions of Brazil. These mortars are used as X-ray shielding elements and aim at providing efficiency and quality of shielding projects, thus assuring adequate protection to the public in general and also to the staff occupationally exposed to X radiation.

2. MATERIALS AND METHODS

The experimental procedure employed in this research to determine the mass attenuation coefficient (μ/ρ) was: using Diagnostic X-ray qualities RQR4, RQR6, RQR9 and RQR10

(IEC, 2005), a beam of photons of variable energy went through a collimator and hit samples of barite mortar made in the shape of plates. The beam of photons transmitted went through another collimator and reached an X-ray detector - type CdTe. This detector was calibrated for sources of ^{241}Am, ^{133}Ba, ^{109}Ca. The measurements of attenuation of the X-ray beams were obtained in good geometry conditions, with a narrow beam, aiming at reducing the quantity of scattered radiation reaching the detector. For this purpose, barite mortar plates, in thickness which allowed the radiation transmission in a range of values between 50% - 2% were selected. From the fraction of the intensity transmitted, the kerma in the incident air was calculated for each of the thickness of the material. The respective inclination of the line is (μ/ρ), which expresses the neperian logarithm (ln) of the intensity transmitted against the thickness of the barite mortar.

In a second methodology adopted, the atomic compositions of the three types of barite investigated (white, beige and purple), were also used in the calculation of the theoretical (μ/ρ) by employing the WinXcom programme for windows. By using the percentage of the elements which compose each barite mortar, the values of the mass attenuation coefficient, in function of energy, with values provided by the XCOM/NIST (BERGER, 1999) database were obtained; for comparison with the experimental data measured, using the attenuation values calibrated in the X-ray spectrometry

3. RESULTS AND DISCUSSION

The attenuation coefficients measured were obtained from the inclination of the line through a linear adjustment of the plot of the transmission logarithm in function of the thickness of each barite material. Figure 1 depict the graphs of transmission (50% a 2%) in function of thickness for white, cream and purple barites. In these figures, a good agreement between the values measured for (μ/ρ) and the values calculated by winXcom for attenuations of 25%-2% (KERUR, 2010) can be observed. According to literature (MORABAD, 2010; SHARNABASAPPA, 2010), for a certain photon energy, the attenuation values may be obtained in function of the thickness of the material investigated within the transmission interval - between 2% and 50%.

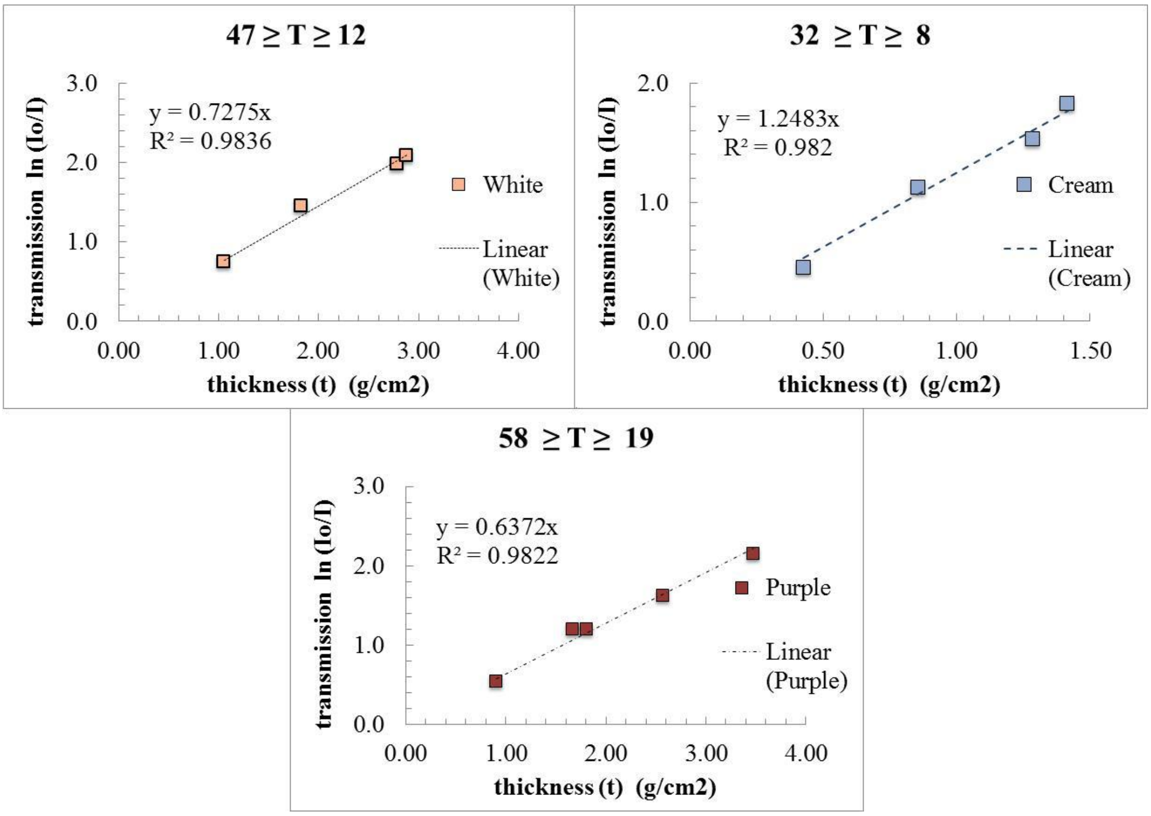

Figure 1. Graph ln (I_0/I) versus thickness for transmission barites white, cream and purple (RQR 9).

The difference between the theoretical value determined by WinXcom using the atomic composition of the samples and the experimental value is attributed to the absorption effect K (k-edge). The existing discontinuities, expressed in Figures 2 and 3, may be attributed to the absorption boundary of each of the composites present in the sample analysed. The mass attenuation coefficient is very sensitive to modification in this discontinuity energy region, (20 to 70 keV). This study shows that the differences between the values of theoretical results and the experimental ones, for mass attenuation coefficients, may be attributed to variation in the chemical composition of the samples and to the nature of the rule of mixtures, which disregards interactions amongst the atoms of the composites. The WinXCom programme is based on the rule of mixture which shows the coefficients of attenuation of any substance, such as the sum of pondered contributions of the individual atoms (POLAT, 2010)).

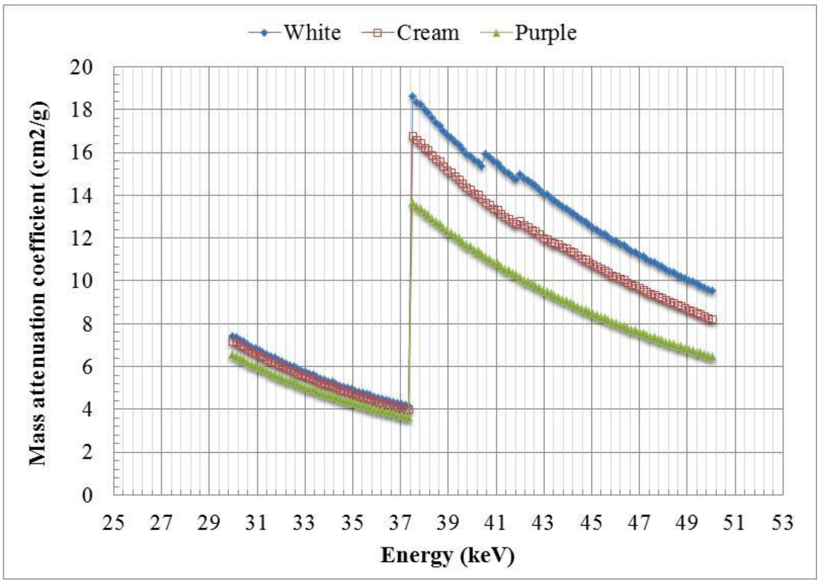

Figure 2. Distribution of mass attenuation coefficients as a function of energy for mortar barite.

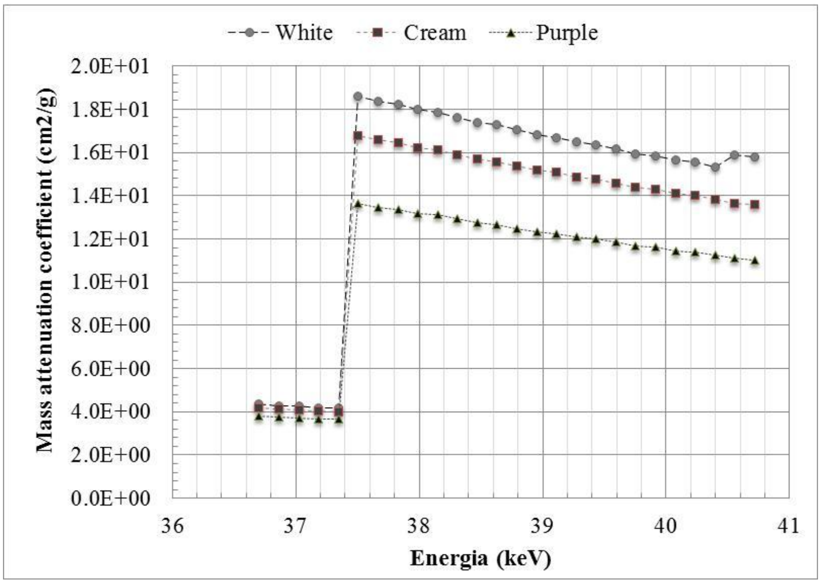

Figure 3. Distribution of mass attenuation coefficient for photon energies 36 keV to 41 keV for mortar barite.

The graph of ln(E) against ln(μ/ρ) is a straight line which shows the variation (μ/ρ) with the energy, as can be seen in Figures 4 to 6. To obtain this linear variation it is necessary that; in the chemical composition of the sample, no element present absorption K near the energy of the incident electron. Otherwise, the graphs presented would not be linear (MORABAD; KERUR, 2010). It can be observed that, near the absorption boundaries of the elements of high atomic numbers, the properties of the radiation attenuation of the materials investigated vary, due to the presence of the following elements that constitute them, for instance: barium, (Ba), silicon (Si) and calcium (Ca).

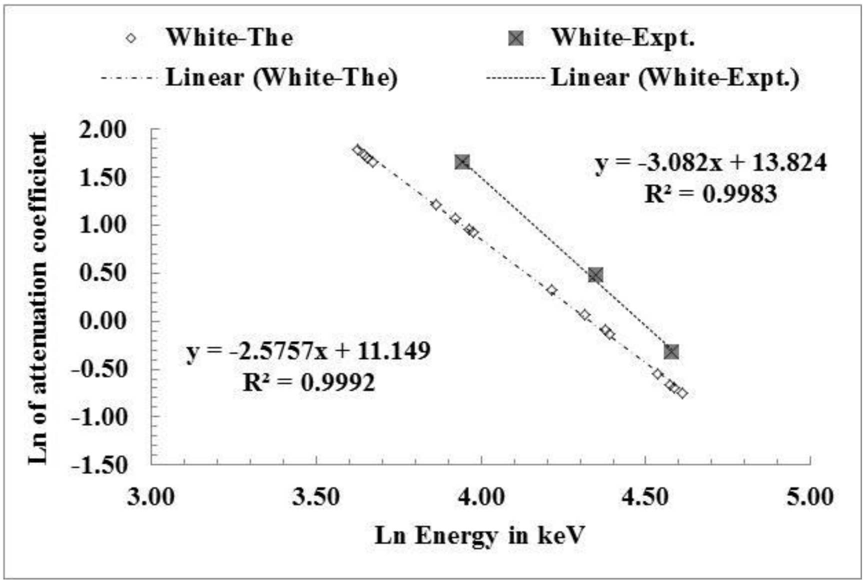

Figure 4. Graph of ln(E) against ln(μ/ρ) in cm^2/g (white barite).

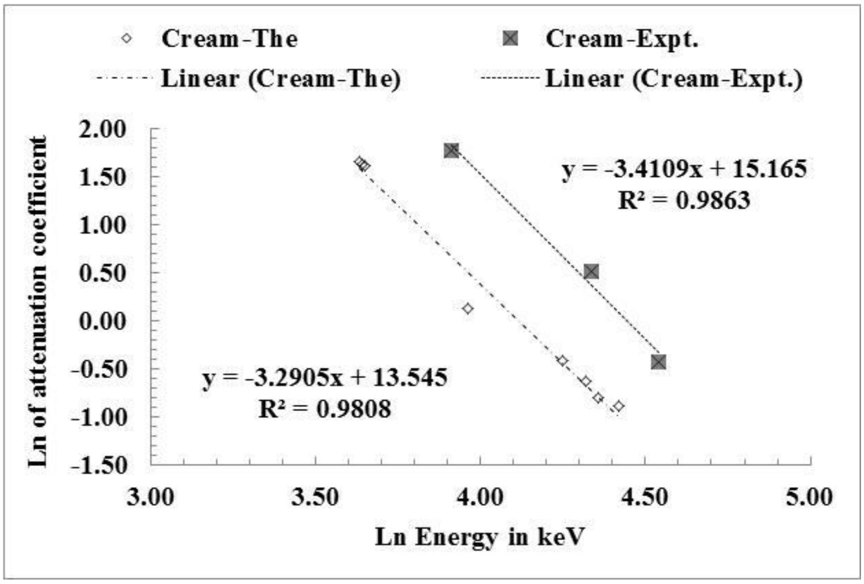

Figure 5. Graph of ln(E) against ln(μ/ρ) in cm^2/g (cream barite).

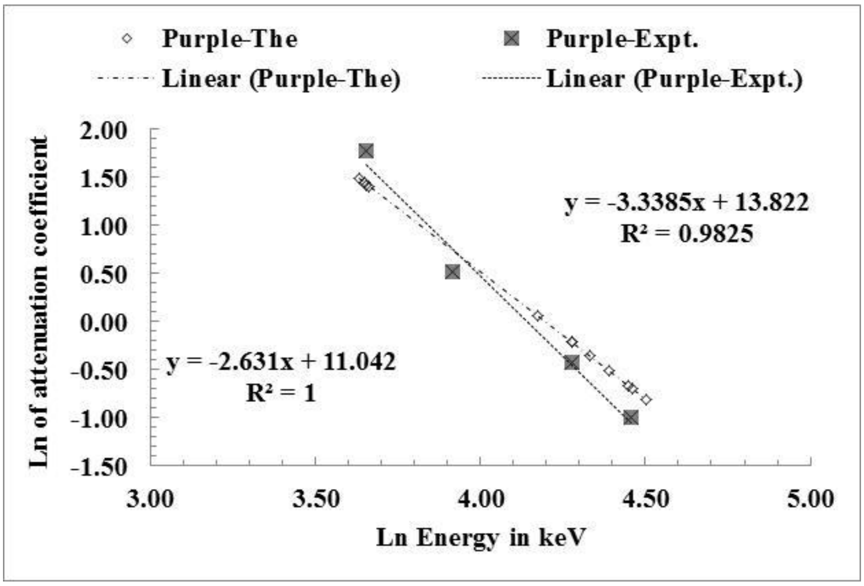

Figure 6. Graph of ln(E) against ln(μ/ρ) in cm^2/g (purple barite).

4. CONCLUSION

In this research, it was possible to show that the characteristics of attenuation of barite influence the transmission curves within reach of the diagnostic X-rays. It was also demonstrated that the composition of the barite influence the transmission curves of the X-rays, thus demonstrating the importance of the determination of the atomic composition of these materials. Moreover, the coefficients of mass attenuation (μ/ρ), in qualities IEC (RQR4, RQR6, RQR9 and RQR10) for the materials of white, cream and purple barites were determined experimentally and calculated by WinXcom. Also, the first and second semi-reducer layers for these materials within the energy ranges of the qualities mentioned were assessed. The determination of these quantities allows for higher reliability, precision and safety in the use and employment of the materials studied.

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