Special issue of the 3rd International Conference on Computational and Experimental Science and Engineering (ICCESEN 2016)

Radiation Transmission of Some Gypsum Concretes for 511, 835 and 1275 keV Gamma Rays

K. Günoğlu*

Suleyman Demirel University, Technical Vocational School, Isparta, Turkey

Although gypsum is one of synthetic building materials, nowadays it is used as interior coating of walls and ceilings of buildings. Thus, measurement of its radiation shielding properties is vital. The gamma attenuation coefficients of gypsum concretes, produced using different rates of boron, have been measured at gamma energies of 511, 835 and 1275 keV. The measured results have been compared with the results of calculation, which has been done using XCOM computer code. The obtained results have also been compared with the normal type of gypsum concrete, in order to see the effect of boron on the radiation shielding properties.

DOI: 10.12693/APhysPolA.132.1022

PACS/topics: 23.90.+W, 78.66.SQ

1. Introduction

After discovery of the radioactivity by Becquerel, radiation started to be used in various fields and nowadays it became a part of our life. Employment of radiation, ranging from industry to medicine, brings its hazardous effect and hence radiation protection is developed in parallel with the utilization of radiation.

People are being exposed to increasing amounts of radiation. In order to be protected from radiation, three different criteria are commonly considered. These are time, distance and the shielding. Shielding is the most effective way of radiation protection. An effective shield should cause a large energy loss on a small distance, without emission of more hazardous radiation.

The linear attenuation coefficient μ is used to determine the radiation shielding properties of a material and it is defined as the probability of radiation to interact with a material, per unit path length [1]. As this subject is very important for health, there are many studies on the linear attenuation coefficient of different materials in the literature. This includes building materials [2–5], alloys [6, 7] and also compounds [8–13].

In the present work, gamma attenuation coefficients of gypsum concretes have been investigated for different gamma energies (511, 835, and 1275 keV) by using point radioactive sources (^{22}Na and ^{54}Mn). The measured results have been compared with the results of calculations.

2. Materials and methods

The gamma attenuation coefficients of gypsum concretes, containing boron fractions of 0, 5 and 10%, were measured at gamma energies of 511, 835 and 1275 keV. The measurements have been performed using a low gamma level counting spectrometer (Fig. 1), based on a $3'' \times 3''$ NaI(TI) detector by ORTEC Inc., connected to a multichannel pulse height analyser [14]. The necessary power for the detector, as well as the acquisition of gamma spectra was achieved by an integrated spectroscopic system. This system is controlled by a personal computer. The control of acquisition parameters and analysis of the collected spectra are carried out using MAESTRO-32 (version 6.06) software package.

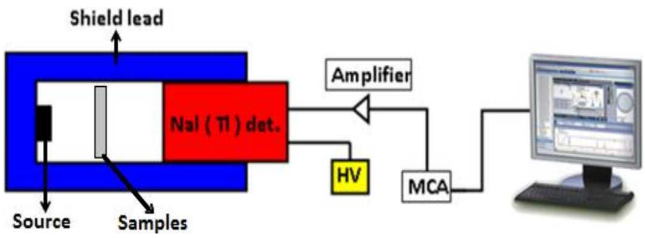

Fig. 1. Schematic view of gamma spectrometer and electronic units.

The photon attenuation coefficients have been evaluated by comparing I and I_0, which are the count rates measured by the detector, respectively, with and without the absorber of thickness x.

$$\mu = \frac{1}{x} \ln \frac{I_0}{I}. \quad (1)$$

$\gamma-$rays spectra, obtained from ^{22}Na and ^{54}Mn sources, are displayed in Fig. 2, where attenuated I and unattenuated I_0 spectra of γ-rays at 511, 835 and 1275 keV can be clearly seen.

The measured gamma attenuation coefficients μ were compared with the results of calculations for the mass attenuation coefficients μ/ρ, which were obtained using XCOM computer code. The XCOM is a data base which can run on a PC. It uses pre-existing data bases for coherent and incoherent scattering, photoelectric absorption, and pair production cross-sections to calculate mass attenuation coefficients at photon energies of 1 keV–1 GeV [15]. In the XCOM code chemical contents is the input and the mass attenuation coefficient μ/ρ is the output.

*corresponding author; e-mail: kadirgnoglu@gmail.com

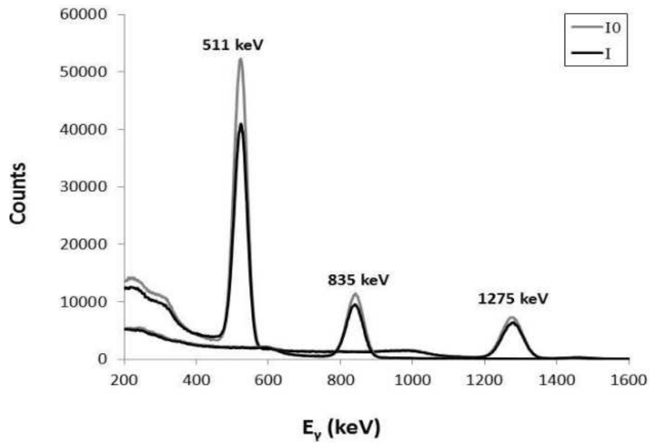

Fig. 2. Spectra of attenuated and unattenuated γ-rays, obtained from ^{22}Na and ^{54}Mn sources.

The effectiveness of γ-ray shielding is described in terms of the half value layer (HVL) or the tenth value layer (TVL) of a material. The HVL is the thicknesses of an absorber that will reduce the radiation to half, and the TVL is the thicknesses of an absorber that will reduce the γ-radiation to one tenth of its original intensity. These values are obtained as:

$$\mathrm{HVL} = \frac{\ln 2}{\mu}, \quad \mathrm{TVL} = \frac{\ln 10}{\mu}. \tag{2}$$

The mean free path is defined as the average distance between two successive interactions of photons and it is given as:

$$\mathrm{mfp} = \frac{1}{\mu}. \tag{3}$$

3. Results and discussion

The gamma attenuation coefficients for gypsum concretes including boron fractions of 0, 5 and 10% have been obtained using gamma spectrometer. All collected results are shown in Fig. 3, where it can be seen that the measured values decrease with increasing gamma energy.

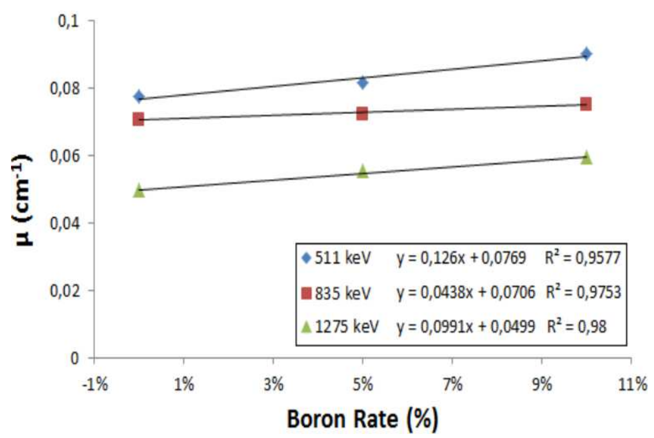

Fig. 3. Gamma attenuation coefficients as functions of boron rate.

In Fig. 3 the gamma attenuation coefficients are also displayed as functions of boron rate in gypsum concretes for 511, 835 and 1275 keV energy, respectively. It can be clearly seen from this figure, that there is a linearly increasing relation between the linear attenuation coefficients and barite content.

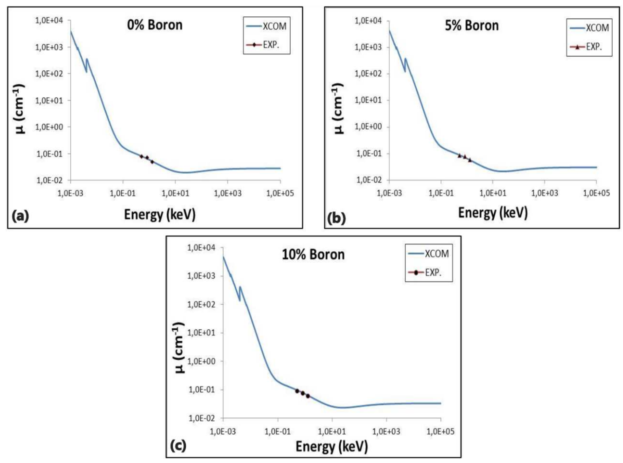

Fig. 4. The linear attenuation coefficient of composite samples as a function of photon energies (a) 0% boron, (b) 5% boron, (c) 10% boron.

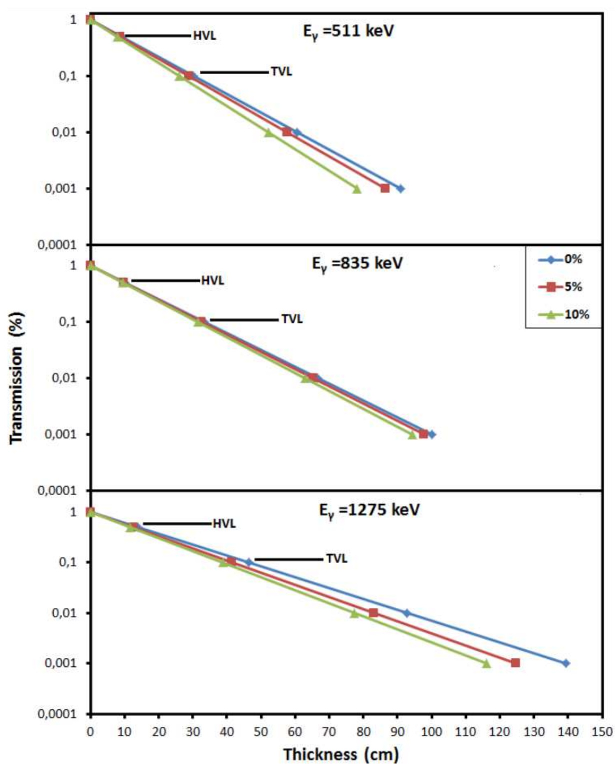

Fig. 5. Percentage of transmitted radiation for composite samples, as a function of thickness at different photon energies.

The linear attenuation coefficients have been calculated at photon energies in the range of 1 keV to 100 GeV and the results were compared with the measurement results. This comparison is displayed in Fig. 4, where it can be seen, that the calculated and the measured results are in a good agreement. It can also be clearly seen from this figure, that the linear attenuation coefficients depend on the incoming photon energies, as the interaction mechanism of photons with the medium is different for different photon energies.

An important information about the thickness of the material required to attenuate gamma-rays of a given energy can be obtained from dependence of transmission rate of the gamma ray on material thickness. Such dependencies for gypsum concretes containing different amounts of boron are displayed in Fig. 5. It can be seen from this figure that the largest thickness is required for sample including 0% of boron and smallest thickness is required for sample including 10% of boron. This can also be seen from the HVL and TVL of materials, which are also indicated in the figure.

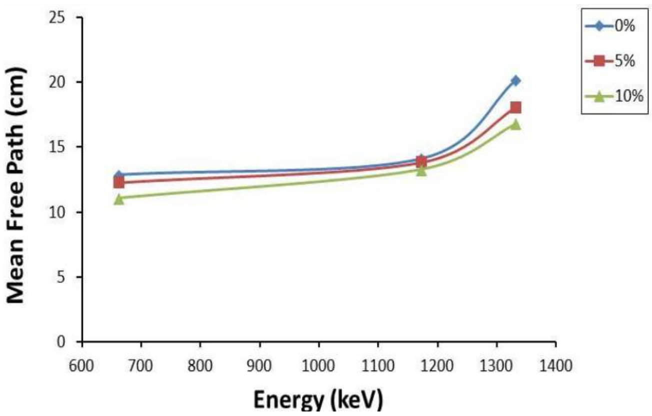

Fig. 6. Variation of mean free path with the photon energies.

The mean free paths have been calculated using the measured linear attenuation coefficients of γ-photon with energies of 511, 835 and 1275 keV. The mfp as a function of photon energy is displayed in Fig. 6, where it can be seen that the low energy photon can lose its energy on shorter distance, while high energy photons need longer distances.

4. Conclusions

The measurement has shown that with the increasing boron rate in gypsum concretes, the gamma attenuation coefficients are also increased.

References

[1] J. Woods, *Computational Methods in Reactor Shielding*, Pergamon, New York 1982.

[2] I. Akkurt, R. Altindag, K. Günoğlu, H. Sarıkaya, *Ann. Nucl. Energy* **43**, 56 (2012).

[3] S. Gedik, A.F. Baytaş, *Acta Phys. Pol. A* **128**, B-174 (2015).

[4] M.E. Medhat, *Ann. Nucl. Energy* **36**, 849 (2009).

[5] C. Singh, T. Singh, A. Kumar, G.S. Mudahar, *Ann. Nucl. Energy* **31**, 1199 (2004).

[6] I. Akkurt, B. Mavi, A. Akkurt, C. Basyigit, S. Kilincarslan, H.A. Yalim, *J. Quant. Spectrosc. Radiat. Transfer* **94**, 379 (2005).

[7] O. Icelli, S. Erzeneoglu, B. Gurbulak, *J. Quant. Spectrosc. Radiat. Transfer* **90**, 399 (2005).

[8] H. Baltas, S. Celik, U. Cevik, E. Yanmaz, *Radiat. Meas.* **42**, 55 (2007).

[9] İ. Akkurt, S. Emıkönel, F. Akarslan, K. Günoğlu, Ş. Kilinçarslan, İ.S. Üncü, *Acta Phys. Pol. A* **128**, B-53 (2015).

[10] U. Turgut, E. Buyukkasap, O. Simsek, M. Ertugrul, *J. Quant. Spectrosc. Radiat. Transfer* **92**, 143 (2005).

[11] I. Akkurt, *Ann. Nucl. En.* **36**, 1702 (2009).

[12] I. Akkurt, K. Gunoglu, S.S. Arda, *Sci. Technol. Nucl. Installations* **2014**, 186798 (2014).

[13] G.S. Bhandal, K. Singh, *Radiat. Phys. Chem.* **47**, 109 (1995).

[14] I. Akkurt, C. Basyigit, S. Kilincarslan, B. Mavi, A. Akkurt, *Cement Concrete Compos.* **28**, 153 (2006).

[15] M.J. Berger, J.H. Hubbell, S.M. Seltzer, J. Chang, J.S. Coursey, R. Sukumar, D.S. Zucker, K. Olsen, *NBSIR 87-3597, Photon cross sections on a personal computer*, National Institute of Standards, Gaithersburg 1987.