Measurement of mass attenuation coefficient for wood at gamma energy range 186 – 1765 KeV.

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Abstract

Mass attenuation coefficient values for Swedish board wood (ρ = 0.5065.g.cm^{-3}) at gamma energies 186.2, 242, 295.2, 351.9, 609.3, 768.3, 1120.3, 1238.1 and 1764.5 KeV were measured by using HPGe detector, the radiation source used in the experiment was ^{226}Ra . These coefficients were also calculated by XCOM code.

The experimental result obtained gives good agreement with calculated values and the mass attenuation coefficient for Swedish board wood obtained in this research was decreased with increasing photon energy.

1. Introduction

Woods have a variety of uses; they can use as packaging materials and as an efficient heat insulator in various interior spaces and furniture works. They can also use as shield for nuclear radiation sources[1,2]

The attenuation of a narrow collimated beam of either gamma or x-rays of a given energy can be obtained by the relationship[2, 3]:

$$I = I_0 \, e^{-\mu \; x} \qquad (1)$$

Where I_0 is the initial intensity of the incident photons before entering a particular attenuating material, I is the transmitted intensity after entering it, x is the attenuating material thickness and μ is the linear attenuation coefficient of the material.

Equation (1) may also be written as:

$$\ln \frac{I_0}{I} = \mu \, x \qquad (2)$$

The linear attenuation coefficient of the material (μ) is determination by plotting $ln(I_0/I)$ against x [2 ,3]. More conveniently a coefficient that is mass attenuation coefficient (μ_m) defined as ($\mu_m = \mu / \rho$) where ρ is material density. μ_m value depends on the photon energy and composition of the interacting medium. μ_m values of gamma rays in several materials are interest for biological, agriculture, industrial and medical studies. They are also needed to solve various problems in radiation physics [3-5].There are a several works have been performed to obtain mass attenuation coefficients theoretical, experimental and compilation for different elements, compounds and mixtures. Some of the authors as *Medhat* (2009) measured mass attenuation coefficient of some building materials in Egypt [6]. *Shakhreet et al*. (2009) measured the mass attenuation coefficient of Rhizophora spp. wood for X-rays in 15.77 – 25.27 KeV range [7]. *Demir et al*. (2008) measured mass attenuation coefficient for soil[8]. *Turkmen et al*. (2008) calculated mass attenuation coefficient in Portland cements mixed with silica fume and natural zeolite over the range 1-2000 KeV [9]. *Jalali* and *Mohammadi* (2008) have measured and calculated mass attenuation coefficient for neutron absorber materials [10]. *Salines et al*.(2006) have calculated the mass attenuation coefficient for several building materials normally used in Brazil [11]. *Akurt et al*. (2005) studied the dependence of mass attenuation coefficient on atomic number (z), using XCOM code [12].

Radium-226 (half-life 1620 years) is a product in the radioactive decay series of uranium-238. In its radioactive decay, the radium-226 emits alpha, beta particles, and gamma rays. Later on, a better determination of ^{226}Ra through the gamma peak 186.21 KeV (3.59%) by using high purity germanium detector (HPGe).

Usually the ^{226}Ra contribution in the gamma spectrum corroborated by taking into account the radioactive ^{214}Bi through gamma peaks 609.31 (46.10%), 768.36 (4.94 %), 1120.29 (15.10%), 1238.1 (5.79 %) and 1764.49KeV (15%) plus the ^{214}Pb peaks at 242 (7.43 %), 295.22(19.3%) and 351.93 KeV (37.60 %) [2, 13].

In the present work, the mass attenuation coefficient have been measured and calculated for wood at all gamma energies mentioned above (186.2, 242, 295.2, 351.9, 609.3, 768.3, 1120.3, 1238.1 and 1764.49KeV).

2. Experimental details

The schematic diagram of the experimental arrangement used for the present measurements is shown in Fig.1.

The gamma ray transmission system consisted of radioactive point source ^{226}Ra with an activity 5 µci .The radioactive source was surrounded by the pin-hole lead collimator (3mm diameter) to obtain a narrow beam of photons .

Wood samples were white Swedish board wood. The density of each block was 0.5065 g. cm^{-3}. Samples were rectangular plates with dimensions 20 cm × 20 cm. The thickness of wood was increased from 1 to 19 cm.

Gamma ray measurements in this work were carried out by using high purity germanium detector (HPGe) with 12.54% relative efficiency and 1.93KeV resolution at 1333 KeV of ^{60}Co.

The detector was coupled to pre-amplifier, amplifier, power supply and computer analyzer with Genie 2000 for data acquisition and analysis the obtain areas. The multi- channel analyzer (MCA) has been calibrated using the gamma rays with ^{137}Cs and ^{60}Co sources.

The detector was putted in a hole of 3cm thick lead to reduce the effect of the background as low as possible. Radiation source was centered at distance of 70 cm vertically above the detector; the samples were centered between them. The number of counts reaching the detector with and without samples under study were recorded. The counting time selected for the measurements was 40 minutes, giving a precision better than 0.2%. Fig. 2 shows the spectrum of the ^{226}Ra radioactive source obtained by using HPGe detector.

3. XCOM code

The calculation of the mass attenuation coefficients has been performed by using XCOM code (version 3.1). It is a computer code developed by Berger and Hubbell to calculate the mass attenuation coefficients (μ_m) for each element, compound and mixture in the photon energy range 1 KeV – 100 GeV [14].

4. Results and discussion

Fig. 3 shows the plot of *ln* (I_0/I) versus thickness (x) for Swedish board wood samples at nine photon energies 186.2, 242, 295.2, 351.9, 609.3, 768.3, 1120.3, 1238.1 and 1764.49KeV. The lines were plotted by using the list squares method. The mass attenuation coefficients with their uncertainties are shown in table 1 together with their theoretical values calculated by XCOM code based on the elemental composition of wood (5.41 Hydrogen, 40.16 Carbon, 0.03Nitrogen and 54.50 Oxygen) [15].

The percentage error about 5% was obtained between the measured values and values calculated from XCOM code. The variation of mass attenuation coefficient with photon energy can also be seen in fig. 4. It can be seen that the mass attenuation coefficient for Swedish board wood depends on photon energy.

Table 1. Experimental and theoretical values of mass attenuation coefficients (μ_m) for Swedish board wood.

Photon energy (KeV)	Experimental μ_m (cm^2/gm)	Theoretical μ_m (cm^2/gm) from XCOM code	Percentage error (%)

186.2	0.12658± 0.00110	0.13300	5.07
242	0.12052 ± 0.00136	0.12160	0.90
295.2	0.11376± 0.00120	0.11320	0.5
351.9	0.10791 ± 0.00118	0.10570	2.04
609.3	0.08292 ± 0.00025	0.08437	1.75
768.3	0.07632 ± 0.00055	0.07600	0.42
1120.3	0.06261 ± 0.00056	0.06340	1.26
1238.1	0.06071 ± 0.00057	0.06026	0.74
1764.5	0. 05085 ± 0.00010	0.05012	1.43

5. Conclusions

The values of mass attenuation coefficient (μ_m) were measured for Swedish board wood at the gamma energy range 186 - 1765KeV.
The measurement results were compared with theoretical results obtained from XCOM code. The comparison between experimental and theoretical results gives a good agreement in all energy range.

The mass attenuation coefficient is dependent on the photon energy, it can be seen that, the mass attenuation coefficient smoothly decrease with the increasing photon energy.

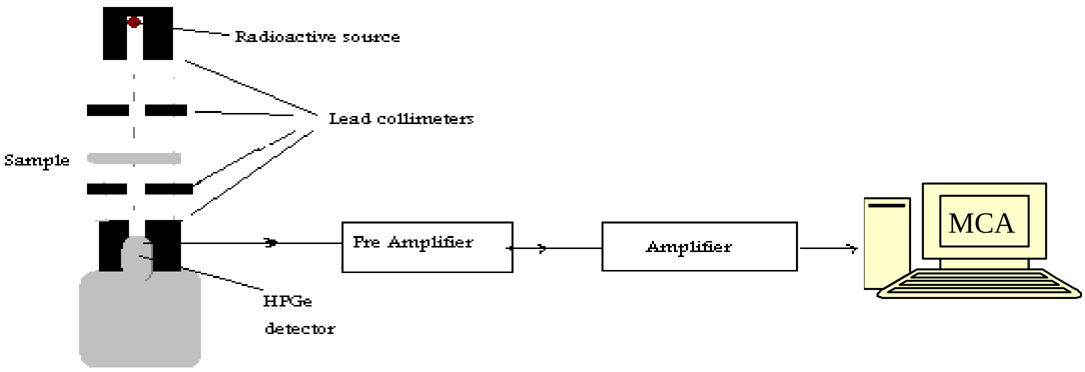

Fig.1: Experimental setup for the measuring of mass attenuation coefficients.

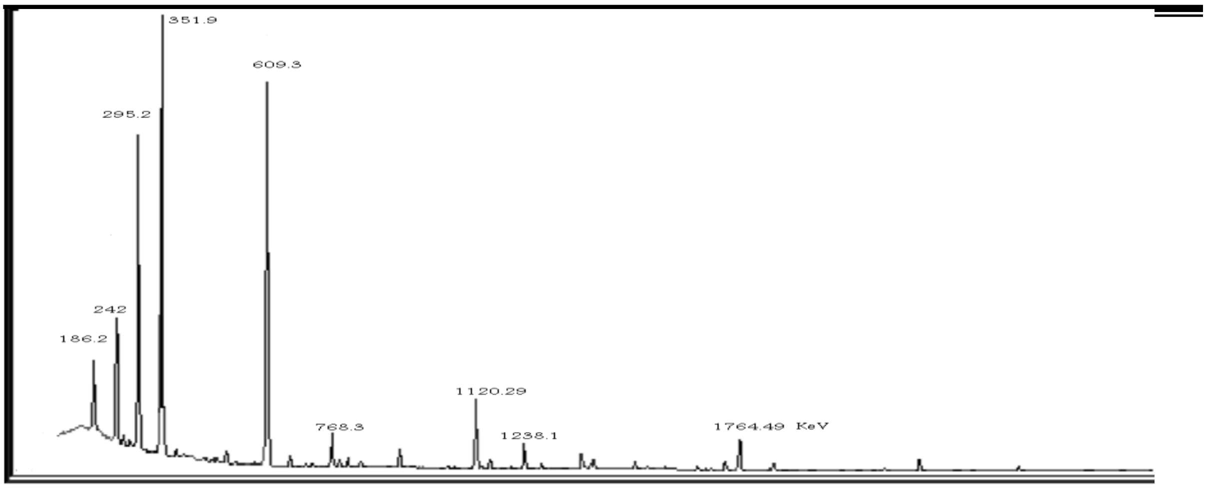

Fig. 2. ^{226}Ra with radioactive decay products ^{214}Pb and ^{214}Bi gamma ray spectrum obtained by using HPGe detector.

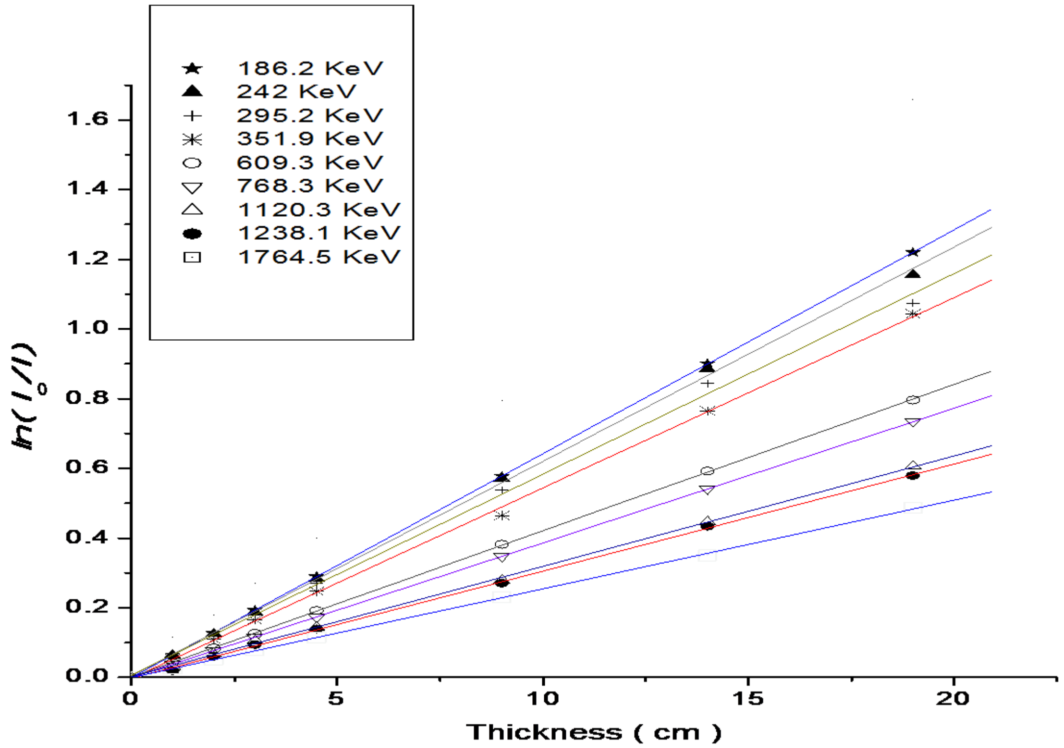

Fig. 3. Plot of $ln(I_o / I)$ versus thickness.

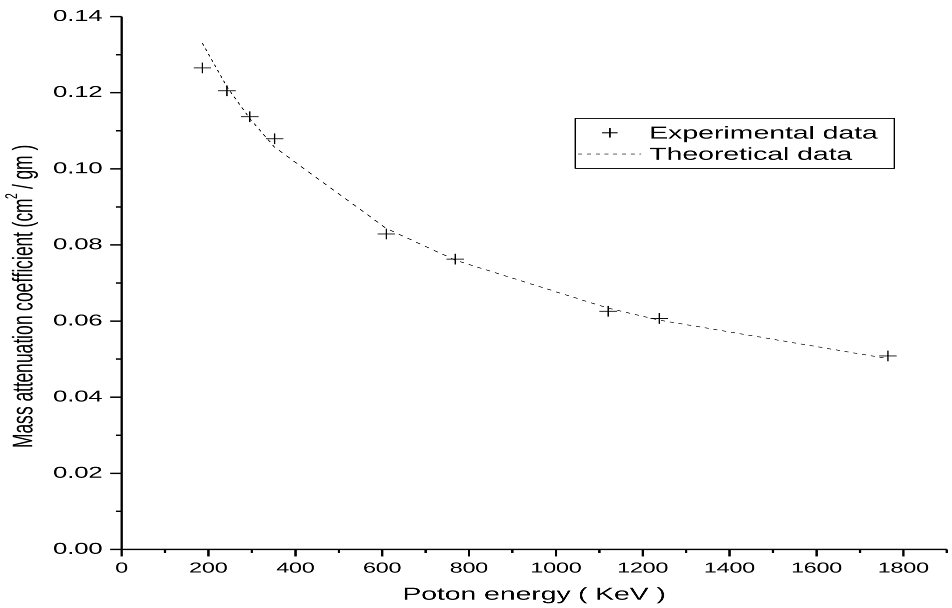

Fig. 4. Variation of experimental and theoretical mass attenuation coefficient for Swedish bord wood with incoming photon energy.

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قياس معامل التوهين الكتلي في الخشب لمدى طاقات أشعة كاما (186-1765) كيلو إلكترون فولت.

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ملخص

تم قياس معامل التوهين الكتلي للخشب السويدي الأبيض ذو الكثافة 0.5065 غرام / سم^3 لأشعة كاما ذات الطاقات 186.2 , 295.2, 351.9, 609.3, 768.3, 1120.3, 1238.1 , 1764.5 كيلو إلكترون فولت باستخدام كاشف الجرمانيوم عالي النقاوة باستخدام المصدر المشع الراديوم–226. كذلك تم حساب تلك المعاملات نظريا باستخدام البرنامج العالمي XCOM . النتائج العملية كانت متقاربة مع النتائج النظرية .

أظهرت النتائج الحاصلة في هذا البحث أن معامل التوهين الكتلي للخشب السويدي المأخوذ يعتمد على طاقة الفوتون

الساقط فيقل بزيادة طاقة الفوتون.