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 ²²⁶Ra. 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]:

\[ I = I_0 e^{-\mu x} \quad (1) \]

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 \( \mu \) is the linear attenuation coefficient of the material.

Equation (1) may also be written as:

\[ \ln \frac{I_0}{I} = \mu x \quad (2) \]

The linear attenuation coefficient of the material (\( \mu \)) is determination by plotting \( \ln(I_0/I) \) against \( x \) [2,3]. More conveniently a coefficient that is mass attenuation coefficient (\( \mu_m \)) defined as (\( \mu_m = \mu / \rho \)) where \( \rho \) is material density. \( \mu_m \) value depends on the photon energy and composition of the interacting medium. \( \mu_m \) values of gamma rays in several materials are interest for...
Measurement of mass attenuation coefficient for wood at gamma energy range 186 – 1765 KeV

Abbas, J. Al-saadi

biological, agriculture, industrial and medical studies. They are also needed to solve various problems in radiation physics [3-5]. There are 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 Mohammad (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 $^{226}\text{Ra}$ through the gamma peak 186.21 KeV (3.59%) by using high purity germanium detector (HPGe).

Usually the $^{226}\text{Ra}$ contribution in the gamma spectrum corroborated by taking into account the radioactive $^{214}\text{Bi}$ 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 $^{214}\text{Pb}$ 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 $^{226}\text{Ra}$ 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
Measurement of mass attenuation coefficient for wood at gamma energy range 186 – 1765 KeV……………………………………... Abbas, J. Al-saadi

Germanium detector (HPGe) with 12.54% relative efficiency and 1.93 KeV resolution at 1333 KeV of $^{60}\text{Co}$. 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 $^{137}\text{Cs}$ and $^{60}\text{Co}$ sources.

The detector was putted in a hole of 3 cm 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 $^{226}\text{Ra}$ 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 ($\mu_m$) 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 1764.49 KeV. 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, 0.03 Nitrogen 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 ($\mu_m$) for Swedish board wood.

<table>
<thead>
<tr>
<th>Photon energy (KeV)</th>
<th>Experimental $\mu_m$ (cm$^2$/gm)</th>
<th>Theoretical $\mu_m$ (cm$^2$/gm) from XCOM code</th>
<th>Percentage error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>186</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>242</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>295.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>351.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>609.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>768.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1120.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1238.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1764.49</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Measurement of mass attenuation coefficient for wood at gamma energy range 186 – 1765 KeV……………………………………. Abbas, J. Al-saadi

<table>
<thead>
<tr>
<th>Energy (KeV)</th>
<th>Mass Attenuation Coefficient (µm)</th>
<th>Theoretical Value</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>186.2</td>
<td>0.12658 ± 0.00110</td>
<td>0.13300</td>
<td>0.00628</td>
</tr>
<tr>
<td>242</td>
<td>0.12052 ± 0.00136</td>
<td>0.12160</td>
<td>0.00108</td>
</tr>
<tr>
<td>295.2</td>
<td>0.11376 ± 0.00120</td>
<td>0.11320</td>
<td>0.00056</td>
</tr>
<tr>
<td>351.9</td>
<td>0.10791 ± 0.00118</td>
<td>0.10570</td>
<td>0.00221</td>
</tr>
<tr>
<td>609.3</td>
<td>0.08292 ± 0.00025</td>
<td>0.08437</td>
<td>0.00147</td>
</tr>
<tr>
<td>768.3</td>
<td>0.07632 ± 0.00055</td>
<td>0.07600</td>
<td>0.00032</td>
</tr>
<tr>
<td>1120.3</td>
<td>0.06261 ± 0.00056</td>
<td>0.06340</td>
<td>0.00079</td>
</tr>
<tr>
<td>1238.1</td>
<td>0.06071 ± 0.00057</td>
<td>0.06026</td>
<td>0.00045</td>
</tr>
<tr>
<td>1764.5</td>
<td>0.05085 ± 0.00010</td>
<td>0.05012</td>
<td>0.00073</td>
</tr>
</tbody>
</table>

5. Conclusions

The values of mass attenuation coefficient (µm) 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.](image)

MCA
Measurement of mass attenuation coefficient for wood at gamma energy range 186 – 1765 KeV ……………………………………… Abbas, J. Al-saadi

Fig. 2. $^{226}$Ra with radioactive decay products $^{214}$Pb and $^{214}$Bi gamma ray spectrum obtained by using HPGe detector.
Measurement of mass attenuation coefficient for wood at gamma energy range 186 – 1765 KeV

Fig. 3. Plot of $ln(I\_0/I)$ versus thickness.

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

Abbas, J. Al-saadi
Measurement of mass attenuation coefficient for wood at gamma energy range 186 – 1765 KeV……………………………………. Abbas, J. Al-saadi

References
Measurement of mass attenuation coefficient for wood at gamma energy range 186 – 1765 KeV…………………………………….. Abbas, J. Al-saadi