A study on photon attenuation coefficients of different wood materials with different densities

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Abstract. A study on the variation of linear attenuation coefficients with the densities of the wood samples is under taken. The soft wood and hard wood samples were collected from the forest area of Pakal in Warangal district. The linear and mass attenuation coefficients are measured using gamma ray spectrometry based on NaI (Tl) scintillation detector with energies of 662 KeV and 59.5 KeV respectively. The mass attenuation coefficient values measured from experiment and are compared with theoretical methods using XCOM program. The plots of density versus linear attenuation coefficient for different wood materials correspond to higher order polynomial are presented. It is observed that variation of linear attenuation coefficient depends on densities of materials. The Chloroxylon swietenia with more density has more linear attenuation coefficient at 59.5 KeV and 662 KeV. The variation in attenuation coefficient attributed to chemical composition of wood used in the experiment.

1. Introduction

Shielding from gamma radiation requires large amounts of density. The radiation is better absorbed by materials with high atomic numbers density, although neither effect is important compared to the total mass/area in the path of the gamma ray. For this reason, a lead shield is 25 percent more efficient to a shield gamma radiation than an equal mass of another shielding material such as aluminum, concrete, or soil, or same quantity of water. Lead's capability of shielding radiation is associated with density. The higher the energy of the gamma rays, the thicker the shielding required. Materials for shielding gamma rays are typically measured by the thickness required to reduce the intensity of the gamma rays by one half (the half value layer or HVL). However, the mass of this much concrete or soil is only $20 - 30$ percent larger than that of this amount of lead. Depleted uranium is used for shielding in portable gamma ray sources, but again the savings in weight over lead is modest, the main effect being reducing the shielding bulk. Now a days wood, as one of the main materials, cheap as compared to lead and other better shields, used in modern building construction, and its method of production in the subject of detailed scrutiny, particularly where the buildings are of critical importance such as a hospital.

Some investigations in the period of 1900 - 2000 is presented by Mortatti and Fillo [1]. They have used a method to study ten different samples using 662 KeV and 59.54 KeV gamma-rays. Barros-Ferraz and Rezenda [2] used the method to study the density variability in two different samples of pine wood using Am^{241} at 59.54 KeV, with a view to understand their efficiency and adaptation. A new method of water content gradation in wood based on low-energy gamma ray attenuation in pine wood samples are developed by Aguiar and Barros-Ferraz [3]. They showed that the method is quick, nondestructive and has reliably good sensitivities for moisture contents varying from 30 to 90 percent. Miranda, Regina and Pascholati [4] studied gamma attenuation in natural wood, dry wood and dry leaves using Am^{241} gamma rays and they found that the variation is small among different species. The challenge of the research activity in wood science and technology must be oriented to the development of non-contact, nondestructive techniques which can be used in situ and in vivo and not induce any structural damage in samples of various sizes ranging from small clear laboratory specimens to trees, structural elements, and industrial-size wood-based panels [5,6]. The gamma-ray attenuation technique is used to determined the wood density and moisture content and is recommended by the investigators [7,8]. The gamma ray source Cs^{137}, the photon peak which has energy of 662 KeV for determination of attenuation coefficients is used in research work [9,11].

Attenuation coefficient is an important parameter for the study of interaction of radiation with matter and indicates the fraction of energy scattered or absorbed [12]. The probability of a photon interaction with a given material, per unit path length, is called the 'Linear attenuation coefficient'. This coefficient is of great importance in radiation shielding materials. Linear attenuation coefficients depend on the shielding material. The density often does not have a unique value but depends on the physical state of the material such as, in the case of wood, the moisture content. To prevent the effects of variations in the density of a material, the linear attenuation coefficient is expressed as mass attenuation coefficient which is the linear attenuation coefficient per unit density of the material [13]. Recently, Saritha and Rao [14-15] have made experimental and theoretical investigations to determine mass attenuation coefficients of complex biological molecules such as wood samples having H, C, N and O elements.The present work is to estimate attenuation of the gamma-ray of different wood samples with different densities. The mixture rule (see eq. (1) below) has been used for measuring mass attenuation coefficients. Gamma ray sources Am^{241} and Cs^{137} with energies of 59.54 KeV and 662 KeV have been used in these studies.

2. Experimental details

Gamma ray spectrometry system with NaI(Tl) detector high efficiency is used with present study. The spectrum is analyzed using the software PHASTE. The detector is shielded using 4 to 5 inches lead on all sides to reduce the back ground level of the system. The spectrum calibration is carried out using gamma ray sources Am^{241} and Cs^{137} at energies 662 KeV and 59.5 KeV for the wood sample. Attenuation values are plotted against the density of wood samples for particular gamma ray narrow beam geometry. In the present investigation, two points are systematically located on either side of the centered of the peak. In this method we can correct the multiple scattering. After noting the counts without sample (I_0), samples of known thickness (I) are placed in between the collimators placed before the detector and the mass attenuation coefficient is calculated using the well known Lambert's law:

$$\frac{I}{I_0} = exp(-\mu t). \tag{1}$$

The experimental setup as shown in the figure consists of two collimators, one at the front of the detector and another at the front of source that is placed in between the detector and source having 2^o of scattered angle. Fig-1 shows the experimental set up. A direct measurement of source is first taken and then each sample in between the collimators is taken. By this procedure, the intensity of gamma ray with out sample I_0 and that of with wood I is determined and the ration I/I_0 is calculated for each sample. The linear and mass attenuation coefficient for different wood materials are measured with narrow beam geometry (mono energetic transmission beam) for energies 59.5KeV and 662KeV. The linear attenuation coefficients with corresponding

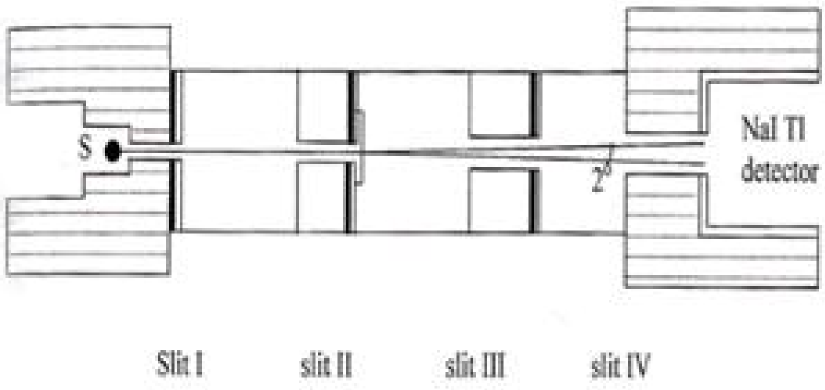

Figure 1. Schematic diagram problem.

Table 1. Density related mass attenuation coefficient of different wood samples for 59.5 KeV.

S.No	Wood sample name	Mass attenuation coefficient	Density(g/cm^3)
1	Sterculia urens	0.209 ± 0.004	0.340
2	Albiziz amara	0.194 ± 0.003	0.721
3	Lagerstroemila parviflora	0.195 ± 0.003	0.975
4	Ziziphus Xylopyras	0.199 ± 0.003	0.695
5	Albiziz adara	0.194 ± 0.003	0.859
6	Pterocarpus marsupium	0.192 ± 0.003	0.747
7	Chloroxylon swietenia	0.193 ± 0.003	1.186
8	Terminalia alata	0.194 ± 0.003	0.929
9	Wrightia tinctoria	0.201 ± 0.004	0.818
10	Cochlospermum religiosus	0.206 ± 0.004	0.306

Table 2. Density related mass attenuation coefficient of different wood samples for 662 KeV.

S.No	Wood sample name	Mass attenuation coefficient	Density(g/cm^3)
1	Sterculia urens	0.080 ± 0.002	0.340
2	Albiziz amara	0.081 ± 0.002	0.721
3	Lagerstroemila parviflora	0.079 ± 0.002	0.975
4	Ziziphus Xylopyras	0.081 ± 0.002	0.695
5	Albiziz adara	0.080 ± 0.002	0.859
6	Pterocarpus marsupium	0.080 ± 0.002	0.747
7	Chloroxylon swietenia	0.081 ± 0.002	1.186
8	Terminalia alata	0.081 ± 0.002	0.929
9	Wrightia tinctoria	0.083 ± 0.002	0.818
10	Cochlospermum religiosus	0.082 ± 0.002	0.306

densities of samples are given in tables 1 and 2. After collection, the samples dried in air up to one year and samples were cut into different dimensions having different densities.

3. Results and discussion

The mass attenuation coefficient (μ/ρ) for different wood samples is measured for the two energies 59.5 KeV and 662 KeV. For each energy, the measurements for all types of samples are carried out in three dimensions. In this investigation, ten wood samples namely Sterculia urens, Albizia amara, Largerstroemia parviflora, Ziziphus xylopyrus, Albizia odaratisma, Pterocarpus marsupium, Chloroxylon swietenia, Terminalia alata, Wrightia tinctoria, and Cochlospermum religious are used with their absolute uncertainties.

For sample 1, the theoretical error for wood samples rangeses from 0.003 % to 0.004 % where as experimental error is 0.004 % and no difference is observed in between com values and experimental values in sample 1. In sample 2, the difference is 0.003.

Linear attenuation coefficients versus different densities of wood samples are plotted and depicted graphically in figure 2. The best line of fit in the form of equation is given below.

$$Y = -0.000x^4 + 0.011x^3 - 0.087x^2 + 0.263x - 0.116,\ R^2 = 0.829,$$
$$Y = -0.000x^4 + 0.005x^3 - 0.0367x^2 + 0.111x - 0.051,\ R^2 = 0.838.$$

The R^2 is the coefficient of determination is a statistical measurement of how will the regression line approximately the real data points. From the numerical results, the value 1.00 of R^2 shows that the regression line perfectly fits the data. From the figure 2, it is clear that the

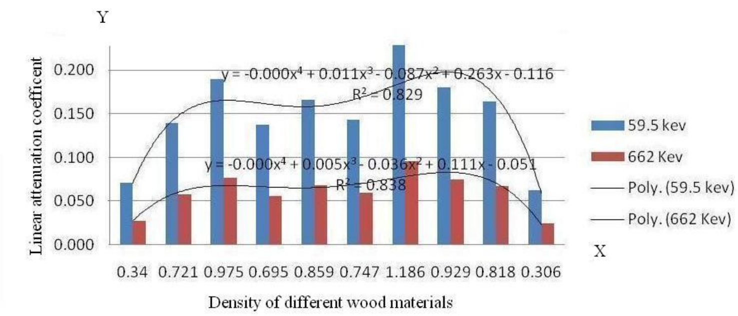

Figure 2. Linear attenuation coefficient versus density of different wood materials.

trend follows higher order polynomial. Here, it is observed that linear attenuation coefficient increases as density increases. Also linear attenuation coefficient decreases as density decreases as shown in figure. The density of Chloroxylon swietenia has more linear attenuation coefficient at 59.5 KeV and 662 KeV. This might be due to chemical composition present in the wood. On examination of the measured photon linear attenuation coefficient for softwood and hard wood materials are across the energies 59.5 KeV and 662 KeV. There are slight differences between the results; there may be due to the composition variation among the different types of soft and hard wood materials. In Chloroxylon swietenia, which is much denser than the other hard wood material showed photon linear attenuation more than the other material under study. The linear attenuation coefficient values of the wood samples varied with the physical density of the materials, increased with increasing in density of the material, increased with increase in density for the same gamma ray energy, and this may decreased with increase of gamma ray energy for the same material. Further the mass attenuation coefficients for all the kinds of samples is studied with respect to the corresponding photon energies and is conducted that they follow exponential law.

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