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Investigation of Gamma Radiation Shielding Characteristics for Various Wood Slabs by Using Gamma Attenuation Method

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Abstract*— *Gamma mass attenuation coefficient and linear attenuation coefficient for various wood slabs are measured using gamma attenuation method. In the present work, ^{137}Cs source (gamma energy) NaI (Tl) scintillation detector and ST360 counter are used. The various wood slabs can be used as shielding material for radioactive substances. The experimental results of linear and mass attenuation coefficients for seven absorbers are compared. These absorbers can be used as shield material for radioactive substances in shield design.

Keywords*— *Linear attenuation coefficient, Mass attenuation coefficient, NaI (TI)scintillation detector.

I. Introduction

Radiation shielding is essential for the protection of human and environment because the harmful effects of ionizing radiations can cause significant health hazards. With the development of technology, human health has started to be exposed to extra radiation and this can damage the human cell [1]. Various materials, placed between a source and a detector, can affect the amount of radiation transmitted from the source to the detector. Such effects are due to attenuation and absorption of the emitted radiation in the source itself, in material used for encapsulation of the source, or in a shielding barrier [2].

There are many types of radiation which may be injurious to health; the primary ones of concern being gamma rays, x-rays and neutron particles. It is widely accepted that if adequate shielding is provided for these forms, the effects from the others can be considered negligible [3]. Theoretically, all materials could be used to attenuate the radiation to safe limits, however, due to certain characteristics, lead, copper, concrete and wood are among the most commonly used materials [4].

The choice of shield material depends on many varied factors such as final desired attenuated radiation levels, ease of heat dissipation, resistance to radiation damage, required thickness and weight, multiple use considerations, uniformity of shielding capability, permanence of shielding and availability. A shield material is expected to have high photon attenuation coefficient in orders that a small thickness will produce significant reduction in intensity.

Since the turn of the 20th century human lifestyle and environment have changed due to the drastic increase in the number of radiation sources such as communication devices and high-energy medical equipment. In order to protect human from the hazardous effects of these radiations, metal shields and non- metallic shields such as polymers are most often employed. The quest for reducing the cost of importing expensive metallic and non-metallic shields by replacing them with more affordable and ubiquitous hard woods.

Wood is a good foreign earner in the country and the development of wood composites as low cost radiation shielding material will certainly add more economic value to the woods. The attenuation coefficient related inversely to the gamma energy and directly with the density of the wood species.

In this paper seeks to measure radiation attenuation properties of various hardwoods and softwoods for gamma energy 662keV (137Cs). The attenuation properties discussed are: Linear Attenuation (μ), Mass Attenuation (μ/ρ). The paper shall further seek to explore the suitability of replacing shielding materials like lead, concrete and copper shields with these tropical wood species especially for use as shielding for low energy gamma ray diagnostic applications.

Linear attenuation coefficients depend on the densities of woods; there exists a linear proportionality. High attenuation coefficient corresponds to a high density of woods. Attenuation coefficients and density are characteristics that can best be used in sorting radiation attenuation abilities of wood species. When lead is specified for a radiation shielding application, regardless of its form or shape, the purity of the selected grade is related to the nature of the radiation source. In some instances, the common impurities that might be found in lead could become secondary radiation emitters. However, some tropical wood species have been found to provide shielding against ionizing radiation (X-rays, gamma rays); these could be employed to replace imported lead shields due to its availability. The attenuation coefficients also depend on the energy[6]. In the present work, attenuation coefficients of various wood slabs for different thicknesses was analyzed and compared.

II. Materials and Methods

Spectrometry System

In the present work 3″ × 3″ NaI (Tl) gamma ray detector (802-5) was used for measuring gamma radiation transmitted intensity through the absorber samples. A sample of each wood under study was placed midway between detector and gamma ray Cs-137 source. The distance between the source

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and the detector was 16cm. Gamma ray intensity for each sample was counted for fixed time period of 300 seconds.

Standard Source

The standard gamma ray Cs-137 source of activity strength 5 µCi was used in the present work. This source was collected from the Nuclear Research Laboratory of the Department of Physics, University of Yangon. Cs-137 gamma source has half- life of 30 years and gamma energy of 662 keV. This source of gamma radiation was selected to study the low gamma ray interaction such as photoelectric and Compton scattering interaction with wood materials.

Absorber Preparation

The five hardwoods (Teak, Iron Wood, Rubber, Yamane, Keruing) and two softwoods (Pine, Rain Tree) were obtained from Myanmar Timber Enterprise (MTE) of Branch (3) at Gyogone Forest Compound, Insein Township, Yangon Myanmar (Table 1).

TABLE 1. List of Wood Species

No	Botanical Names	Local Names	Type
1	*Tectona grandis Linn*	Teak	Hard
2	*Xylia delabriformis*	Iron Wood	Hard
3	*Hevea braziliensis*	Rubber	Hard
4	*Gmelina arborea*	Yamane	Hard
5	*Dipterocarpus baudii*	Keruing	Hard
6	*Pinus spp*	Pine	Soft
7	*Albizia lebbeck*	Rain Tree	Soft

In order to shadow the detector various of wood boards (Teak, Iron Wood, Rubber, Yamane, Pine, Keruing) were cut into sizes of 11.7cm × 7cm × 1.6 cm. The samples were dried up at room temperature of 28°C for a period of 15 days. During this time they were weighed continuously and their weights monitored until the rate of change in weight became less than 0.1 % per day. They were then considered stable to changes in moisture content with time**.** Five different thicknesses for each kind of absorber are chosen to use in this research work.

Experiment procedure and Measurement

The experimental set up used in these investigations shown in Fig 1. In this research work, NaI (Tl) scintillation detector was used to detect the gamma radiation after passing through the layers. The operating voltage for the scintillation detector used in this work is 870V.

The various wood slabs with different thickness are placed in the path of the monoenergetic gamma rays and the detector response noted. The gamma rays source (137Cs) is situated in the lead container, which provides collimation for the incident beam. The spectra and net count data which pass through the layers from the 137Cs (662keV) standard source were collected by ST360 counter in 300s each. And then, linear attenuation coefficient and mass attenuation coefficient of various wood slabs with different thicknesses were calculated.

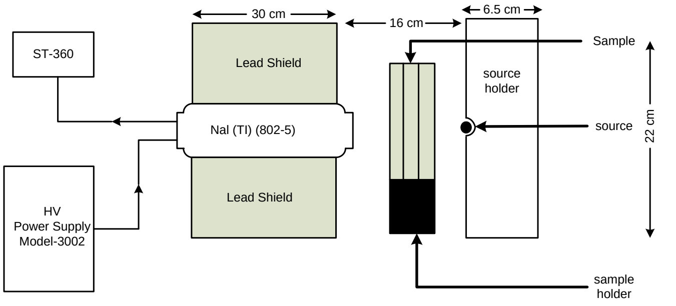

Fig. 1. Block Diagram of Experimental set up

III. Discussion

The gamma transmissions of various woods slabs with different thicknesses by 662keV were listed in Table (2). The gamma transmissions were exponentially decreased with increasing thicknesses (gcm^{-2}) as shown in Fig. (2).

TABLE 2. Gamma Transmissions of Various Woods Slabs with Different Thicknesses

Wood Samples	Thickness (x)		Linear Attenuation (cm^{-1})		Mass Attenuation (cm^{2}g^{-1})	
	(cm)	(gcm^{-2})	$\mu_{(cal)}$	$\mu_{(meas)}$	$\mu/\rho_{(cal)}$	$\mu/\rho_{(meas)}$
Teak	1.7	0.91	0.030	0.021	0.056	0.0454
	3.4	1.66	0.027	0.021	0.054	0.0454
	5.1	2.43	0.025	0.021	0.051	0.0454
	6.8	3.19	0.024	0.021	0.05	0.0454
	8.5	3.98	0.022	0.021	0.047	0.0454
Iron Wood	1.9	1.47	0.033	0.038	0.042	0.0509
	3.9	2.89	0.034	0.038	0.046	0.0509
	5.8	4.29	0.034	0.038	0.047	0.0509
	7.7	5.73	0.036	0.038	0.049	0.0509
	9.6	7.14	0.038	0.038	0.049	0.0509
Pine	1.7	0.91	0.03	0.021	0.056	0.0454
	3.4	1.66	0.027	0.021	0.054	0.0454
	5.1	2.43	0.025	0.021	0.051	0.0454
	6.8	3.19	0.024	0.021	0.05	0.0454
	8.5	3.98	0.022	0.021	0.047	0.0454
Yamane	1.8	0.64	0.015	0.017	0.042	0.0483
	2.6	1.25	0.017	0.017	0.048	0.0483
	5.3	1.85	0.017	0.017	0.051	0.0483
	7	2.45	0.017	0.017	0.049	0.0483
	8.6	3.05	0.017	0.017	0.047	0.0483
Rubber	0.9	0.558	0.033	0.027	0.053	0.042
	2	1.204	0.03	0.027	0.049	0.042
	3.1	1.801	0.026	0.027	0.044	0.042
	4.2	2.508	0.026	0.027	0.044	0.042
	5.1	3.385	0.029	0.027	0.042	0.042
Rain Tree	1	0.298	0.01	0.011	0.034	0.037
	2	0.625	0.01	0.011	0.034	0.037
	2.9	0.897	0.01	0.011	0.034	0.037
	3.8	1.131	0.011	0.011	0.037	0.037
	4.7	1.39	0.011	0.011	0.037	0.037
Keruing	1.7	1.21	0.047	0.042	0.066	0.0527
	3.4	2.4	0.047	0.042	0.066	0.0527
	5	3.69	0.048	0.042	0.065	0.0527
	6.5	4.98	0.045	0.042	0.058	0.0527
	8.1	6.27	0.043	0.042	0.055	0.0527

The linear attenuation coefficients and mass attenuations coefficients of various woods with different thicknesses was calculated by using the following general equations,

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

$$I = I_0\, e^{(-\mu/\rho\,)}\, x$$

The measured and calculated values of mass attenuations coefficients of various woods with different thicknesses were compared. The measured and calculated values of attenuation coefficients were nearly equal (Table 2). The graph of the gamma mass attenuation coefficients Vs different thicknesses(gcm^{-2}) were shown in Fig (4). This figure showed that the attenuation coefficients were not depend on sample thicknesses.

The linear attenuation coefficients depend on the density and the nature of the absorbing materials. The linear attenuation coefficients increase with increasing density of wood materials (Fig 3).

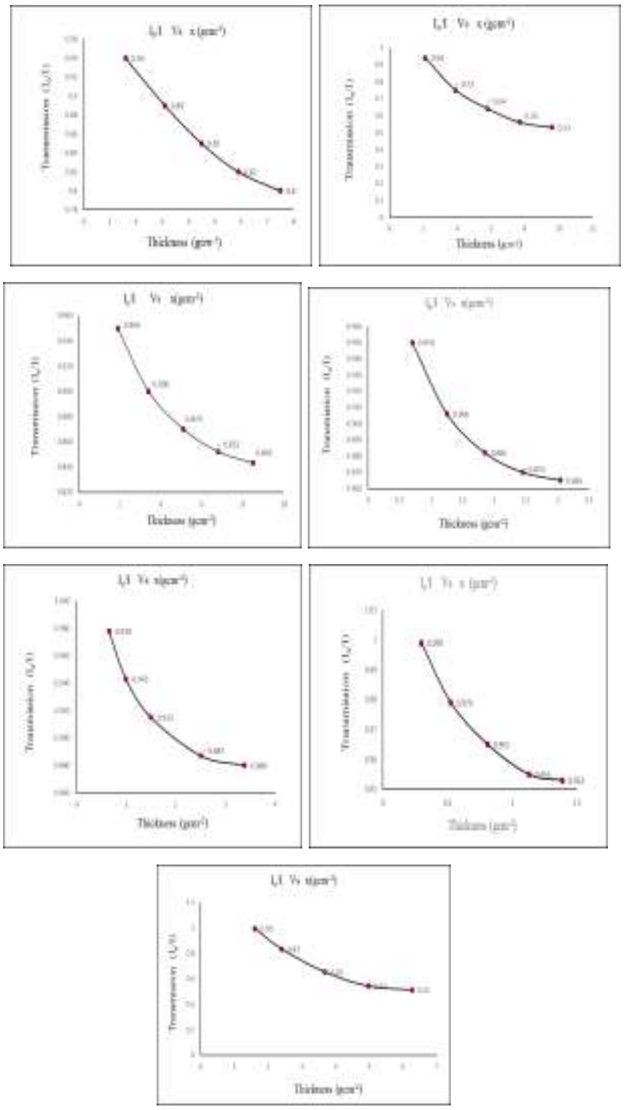

Fig. 2. Net count rate of VariousWood Slabs

Fig. 3. Attenuation Coefficient of various woods with different density

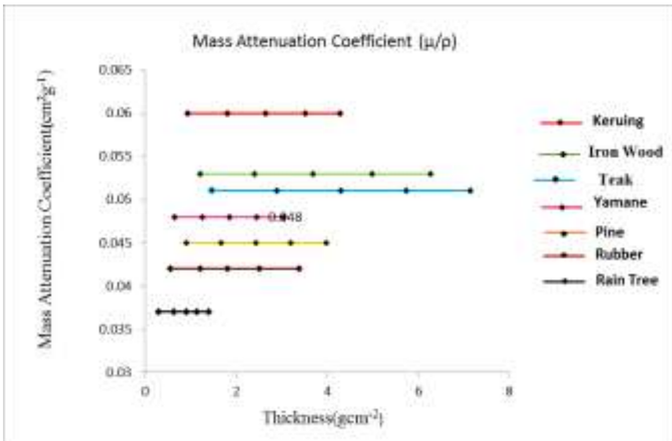

Fig. 4. Mass Attenuation Coefficient of Various Wood

IV. Concluding Remarks

In this study, the measured and calculated values of attenuation coefficients are good agreement for source to detector geometry 16cm with collimator. It means that no scattered radiations were detected by the detector without collimator for above geometry. Thus, it can be concluded that scattered photons from the absorber reach the detector are less and the measurement positions in its research work are the best counting geometry. To get the accurate value of the total mass attenuation coefficients of material, source, sample and detector should be well collimated. In the present work, the attenuation of gamma radiation can be achieved using wood materials.

The density of Keruing is maximum and density of Rain Tree is minimum. Thus, Attenuation coefficient of Keruing is maximum in my present work.

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