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EXPERIMENTAL INVESTIGATION OF GAMMA RADIATION SHIELDING CHARACTERISTICS OF WOOD

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ABSTRACT

Gamma radiation shielding characteristics such as linear attenuation coefficient, mass attenuation coefficient, half- value layer etc; of eight types of wood materials were measured using gamma energy range from 0.511MeV to 1.332MeV. Measurements performed using a gamma spectrometer NaI (Tl) scintillation detector. The intensities of the emergent radiation were measured, when each of these woods were placed between a scintillation detector and radioactive source. Results show that Attenuation coefficient decreases with increase of gamma energy, and attenuation coefficient increases with increase of density and shows significant variation for different species. Attenuation coefficient depends on the energy of incident photons and the nature of the wood material.

KEYWORDS: Attenuation Coefficient, Gamma Radiation, NaI (Tl) Detector, Wood

INTRODUCTION

Studies on interaction of gamma radiation have been the subject of interest for the last several decades. Study of gamma-ray interaction has made profound impact in the fields of atomic physics, radiation physics, material science, environmental science, biology, health physics, agricultural, cancer therapy and forensic science etc. The mass attenuation coefficient is a measurement of how strongly a chemical species or substance absorbs or scatters light at a given wavelength, over a unit mass of material. With the development of technology, human health has started to be exposed extra radiation and this can damage human cell (Elias et al, 1986). In order to be protected from radiation three different methods are commonly used. Those are time, distance and the shielding. The latter one is the most important method in which shielding materials become important.

Attenuation coefficient is an important parameter for study of interaction of radiation with matter that gives us the fraction of energy scattered or absorbed. Wood from all conifers is classified as soft wood, while the wood from all other trees which have broad leaves is termed hardwood. Woods have a variety of uses; they can be used as packaging materials and as efficient heat insulator in various interior spaces and furniture works. They can also be used to shield radiation from nuclear sources. In its many applications, wood may be used as it is or after suitable chemical modification intended to tailor the material properties to those desired in the end-product. Besides the use of wood and new wood composite materials in building and furniture, wood is also extensively used as a source of fibre for pulp and paper and as a source of chemicals for new materials and applications (Sakr et al, 2005). In order to fully understand wood properties and its behaviour when subjected to physical, chemical and biological processes, there is need for future research on wood. This information is very important for the development of new applications of wood and wood derived materials. Gamma radiation from radio nuclides, such as K^{40},Th^{232} and U^{238} series and their decay products, represents the main external source of irradiation to the human body (Auwal et al, 2011).There are many useful applications of gamma ray such as radiotherapy, medical tracer and sterilization. Thus it is important to investigate its some properties such as radiation shielding.

For this purpose the attenuation coefficients of eight wood samples Acacia (*Acacia Nilotica*), Egisa (*Pterocarpus marsupium*), Eucalyptus (*Eucalyptus Melliodora*), Mango(Mangifera indica L), Neem (*Azadirachta indica* L), Rain tree (*Albizia saman*),Redsandal (*Pterocarpus santalinus*), Teak (*Tectona grandis* L) have been measured. For this investigation, gamma energy range from 0.511MeV to 1.332MeV was used to determine the gamma radiation shielding characteristics such as linear attenuation coefficient, mass attenuation coefficient, half- value layer etc; of eight types of wood materials.

MATERIALS AND METHODS

Wood Sample Collection

Wood materials were collected from Nallamala forest, Nandyal Division, Kurnool district, Andhra Pradesh (India).With the help of Divisional Forest Officer (Wild Life), Fresh wood were collected from tree and immediately taken in to the laboratory and kept at room temperature 24 ^{0}C. In the present work dry wood samples were used. List of wood materials shown in table-1.

Table 1: List of Wood Materials was Used in the Present Study

S.No	Scientific Name	Common Name	Family	Type
1	Acacia Nilotica	Acacia(AC)	Mimosoideae	Hardwood
2	Pterocarpus marsupium	Egisa(EG)	Fabaceae	Hardwood
3	Eucalyptus Melliodora	Eucalyptus(EU)	Myrtaceae	Hardwood
4	Mangifera indica L	Mango(M)	Anacardiaceae	Hardwood
5	Azadirachta indica L	Neem(N)	Meliaceae	Hardwood
6	Pterocarpus santalinus	Redsandal(RS)	Fabaceae	Hardwood
7	Tectona grandis L	Teak(TK)	Lamiaceae	Hardwood
8	Albizia saman	Raintree(RT)	Mimosoideae	Softwood

Table 2: Dimensions and Density of Wood

Scientific Name	Length (cm)	Breadth (cm)	Thickness (cm)	Mass (gm)	Volume (cm^3)	Density (gm/cm^3)
Acacia Nilotica	5.08	5.08	5.0	131.47	129.03	1.018
Pterocarpus marsupium	5.08	5.08	5.0	105.86	129.03	0.820
Eucalyptus Melliodora	5.08	5.08	5.0	114.19	129.03	0.884
Azadirachta indica L	5.08	5.08	5.0	97.89	129.03	0.758
Mangifera indica L	5.08	5.08	5.0	111.61	129.03	0.864
Pterocarpus santalinus	5.08	5.08	5.0	125.15	129.03	1.099
Tectona grandis L	5.08	5.08	5.0	97.14	129.03	0.752
Albizia saman	5.08	5.08	5.0	153.49	129.03	1.075

METHODS

The attenuation of gamma radiation is due to the effect of all the energy exchange mechanism such as Photoelectric effect, Pair production and Compton Effect. The Transmitted intensity depends on the density; thickness of the absorbing layer and the cross-sectional properties of the material (Kaplan, 1972). When gamma radiation of intensity I_0 is incident on a material of thickness x, the attenuation of the gamma radiation by the material is given by the relationship.

$$I = I_0 e^{-\mu x} \tag{1}$$

Where I_0 is the intensity of the incident radiation, x is the thickness of the material, I is the intensity after passage.

The attenuation of gamma radiation may also be expressed in terms of a quality called the half-thickness length $x_{1/2}$, defined such that $I(x_{1/2}) = 1/2\ I_0$. Equation (1) may also be written as

$$Ln(I_0 / I) = \mu x \tag{2}$$

Where μ is the attenuation coefficient, Thus from Equation (2), we have it that

$$x_{1/2} = ln(2) / \mu \tag{3}$$

Fron equation (3) we can calculate the half value layer of wood materials.

Measurements of Attenuation Coefficient

The gamma rays were obtained from ^{60}Co, ^{137}Cs and ^{22}Na radioactive sources and the measurements were performed using a gamma spectrometer which contains NaI(Tl) scintillation detector connected to a Multi-Channel –Analyser(MCA). Experimental setup for attenuation measurement is presented in figure-1.First we make standard connections and arrangement between Scintillation detector, absorber and source gamma energy range from 0.511MeV to 1.332MeV was used. Place the absorber (wood material) between end window detector and source holder of respective thickness. We are took the reading for a present time of 10,000 sec. without any absorber and tabulate and repeated the experiment by recording the data stored for the same present time for different thickness in the increasing order (Elias et al, 1990). A typical gamma ray spectrum obtained with ^{22}Na and ^{137}Cs sources both attenuated (I) and unattenuated (I_0) of wood sample at 0.51MeV1 and 0.662 MeV is shown in figure 2. Attenuation measurement can be calculated using equation (2). Repeat the same steps as explained above for next absorber sets of wood.

Figure 1: Experimental Setup for Attenuation Measurement

RESULTS AND DISCUSSIONS

Attenuation coefficient depends on the energy of incident photons and the nature of the absorbing woods. Mass attenuation coefficient obtained from dividing the linear attenuation coefficient with density. Attenuation coefficient decreases with increasing energy and attenuation coefficient increases with increasing density of the wood (Table-3 and Table-4). Table-5 shows that Calculation of Half Value Layer (HVL) of various woods used for the experiment. It can be seen that Pterocarpus santalinus has the lowest half value layer and Acacia Nilotica has the highest half value layer when all energy regions 0.511MeV to 1.332MeV. It means that at the same energy of incident radiation, a lesser thickness of Pterocarpus santalinus will be required to attenuation gamma radiation. A lesser thickness of Pterocarpus santalinus will be required to attenuation gamma radiation to half its original intensity, when compared with other woods used in this experiment. The lowest half value layer of wood has the highest attenuation ability, this implies a good absorber of radiation and highest half value layer of wood has the lowest attenuation ability, this implies the wood is a bad absorber of radiation. From the above results, attenuation coefficient, density and half value layers are characteristics that can best be used in sorting the gamma radiation shielding abilities of wood materials.

Figure 3 shows the plot of ln(I_0 / I) against thickness x for Acacia Nilotica wood sample at 0.511MeV. Attenuation coefficient depends on the densities of woods and a linear proportionality exists between attenuation coefficient and the densities of woods. This means that a high attenuation coefficient corresponds to a high density wood (Table-3 and Table- 2). Pterocarpus santalinus has the highest density amongst other woods collected. The graph in figure-4 shows that, a different exponential curve for the various woods attenuation coefficient decreases with increasing energy. A close look of the attenuation coefficient against energy graph in figure-4 revealed that Redsandal (Pterocarpus santalinus) has the highest attenuation ability and Acacia (Acacia Nilotica) has the lowest attenuation ability when all energy regions 0.511MeV to 1.332MeV are considered. From these results, one can say that the best attenuation is the wood with highest attenuation coefficient, highest density and lowest half value layer.

The descending order of their shielding abilities is as follows: Pterocarpus santalinus, Pterocarpus marsupium, Tectona grandis L, Azadirachta indica L, Eucalyptus Melliodora, Albizia saman, Mangifera indica L and Acacia Nilotica. As a result of high attenuation coefficient, Pterocarpus santalinus is considered a very good absorber and a good material for shielding gamma-rays.

Table 3: Experimental Result of Attenuation Coefficient M (Cm^{-1})

Scientific Name	0.511MeV	0.662MeV	1.173MeV	1.275MeV	1.332MeV
Acacia Nilotica	0.0493	0.0471	0.0422	0.0360	0.0326
Mangifera indica L	0.0564	0.0513	0.0455	0.0436	0.0396
Albizia saman	0.0661	0.0620	0.0553	0.0485	0.0478
Eucalyptus Melliodora	0.0670	0.0625	0.0577	0.0520	0.0496
Azadirachta indica L	0.0718	0.0687	0.0661	0.0643	0.0595
Tectona grandis L	0.0835	0.0806	0.0721	0.0615	0.0522
Pterocarpus marsupium	0.1026	0.0914	0.0675	0.0627	0.0575
Pterocarpus santalinus	0.1050	0.0946	0.0922	0.0798	0.0777

Table 4: Experimental Result of Mass Attenuation Coefficient M/P (Cm^2 /Gm)

Scientific Name	0.511MeV	0.662MeV	1.173MeV	1.275MeV	1.332MeV
Acacia Nilotica	0.0484	0.0462	0.0415	0.0353	0.0320
Mangifera indica L	0.0652	0.0593	0.0526	0.0504	0.0458
Albizia saman	0.0556	0.0521	0.0465	0.0408	0.0402
Eucalyptus Melliodora	0.0757	0.0706	0.0652	0.0587	0.0561
Azadirachta indica L	0.0947	0.0905	0.0871	0.0847	0.0784
Tectona grandis L	0.1109	0.1071	0.0958	0.0817	0.0694
Pterocarpus marsupium	0.1254	0.1114	0.1124	0.0972	0.0947
Pterocarpus santalinus	0.1083	0.0975	0.0696	0.0646	0.0593

Table 5: Result of Calculation of Half Value Layer (HVL) (Cm)

Scientific Name	0.511MeV	0.662MeV	1.173MeV	1.275MeV	1.332MeV
Acacia Nilotica	14.0567	14.7133	16.4218	19.2500	21.2576
Mangifera indica L	12.2872	13.5087	15.2307	15.8944	17.5000
Albizia saman	10.4841	11.1774	12.5316	14.2886	14.4979
Eucalyptus Melliodora	10.3432	11.088	12.0103	13.3269	13.9717
Azadirachta indica L	9.6518	10.0873	10.4841	10.7776	11.6470
Tectona grandis L	8.2994	8.5980	9.6116	11.2682	13.2758
Pterocarpus marsupium	6.7346	7.5820	10.2666	11.0526	12.0521
Pterocarpus santalinus	6.6000	7.3255	7.5162	8.6842	8.9189

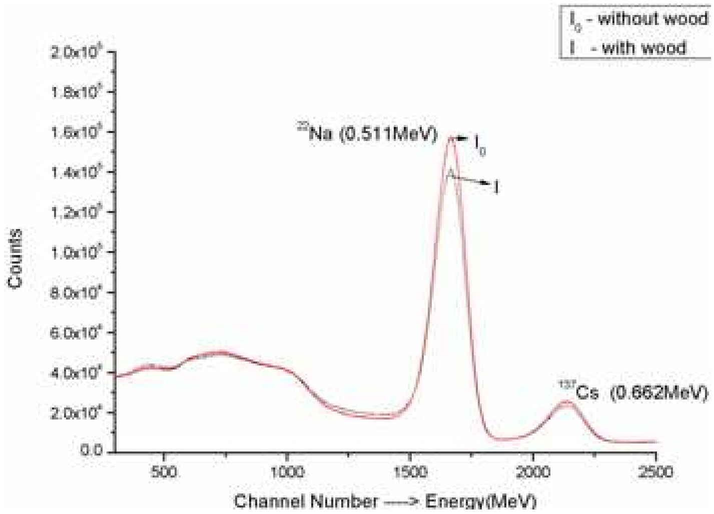

Figure 2: Gamma Spectrum of ^{22}Na and ^{137}Cs Attenuated (I) and Unattenuated (I_0) Wood Samples

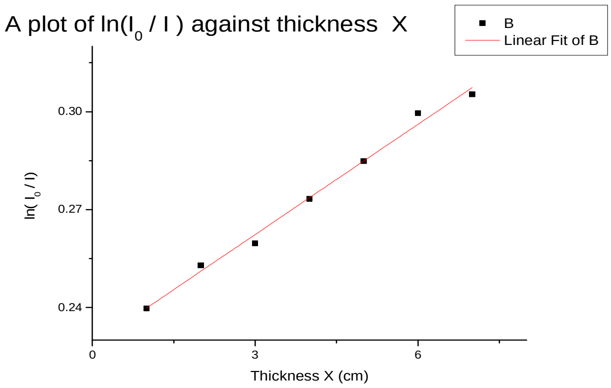

Figure 3: A Plot of Ln(I_0 / I) Against Thickness X for Acacia Nilotica at 0.511 MeV

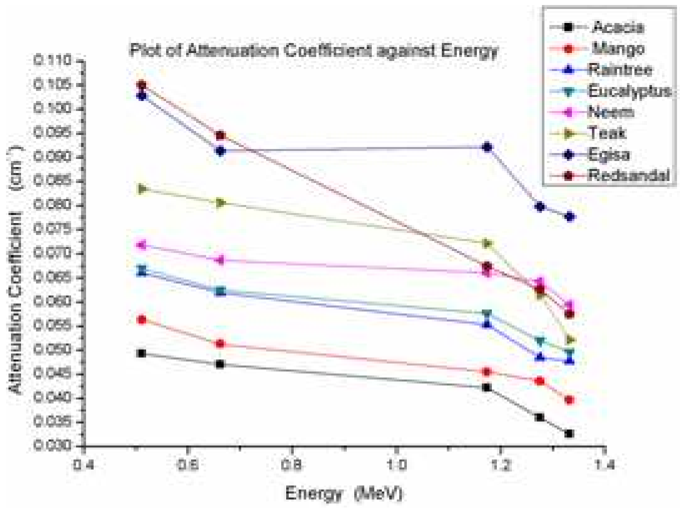

Figure 4: Plot of Attenuation Coefficient against Energy

CONCLUSIONS

In this study attenuation coefficients of gamma rays for wood samples were measured at 0.511MeV to 1.332MeV using a gamma spectrometer NaI(Tl) detector. Attenuation coefficient decreases with increasing energy and attenuation coefficient increases with increasing density of wood. It was observed that in terms of radiation shielding the Pterocarpus santalinus and Acacia Nilotica wood samples were more suitable than other tested wood samples. The study of the shielding characteristics of woods is a necessary research that should continue. It is therefore recommended that more research on shielding ability of material be carried out and using more unexplored tropical woods for radiation shielding applications.

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