Journal of Global Biosciences
ISSN 2320-1355
Volume 4, Special Issue 1, 2015, pp. 1836-1841
Website: www.mutagens.co.in
E-mail: submit@mutagens.co.in
researchsubmission@hotmail.com

Research Paper

COMPARISON OF GAMMA RAY ATTENUATION COEFFICIENTS OF WOOD MATERIALS WITH THEORETICAL VALUES

E. Rajasekhar[1], R. Jeevan Kumar[1], K.L. Narasimham[2] and K. Venkataramaniah[3]

[1]Molecular Biophysical Laboratory,
Department of Physics,
Sri Krishnadevaraya University, Anantapuramu-515003,
Andhra Pradesh, India
[2]Department of Physics,
Kakinada Institute of Technology and Science,
Tirupathi, Divili-533433
[3]Department of Physics,
Sri Satya Sai Institute of Higher Learning,
Prashanthinilayam-515134, India.

Abstract

The experimental mass attenuation coefficients of some wood materials have been determined for comparison with theory. For this study, different types of wood samples were collected from the Nallamala forest area of the Kurnool district, Andhra Pradesh, India. The linear and mass attenuation coefficients of different wood samples are measured by using NaI(Tl) scintillation detector connected to 8K Multi Channel Analyser (MCA) at the gamma ray energies of 662, 1173 and 1332 keV obtained from ^{137}Cs and ^{60}Co radioactive sources respectively. The elemental composition of the wood material was found out by ICP-OES. The experimental values of mass attenuation coefficient are compared with that of XCOM data based tool. The highest value of linear attenuation coefficient obtained for *Acacial nilotica* and the lowest value obtained for *Eucalyptus* at all energies.

Key words: Wood materials, Elemental composition, Attenuation coefficient, Mass attenuation coefficient, NaI(Tl) scintillation detector, Gamma energy source.

INTRODUCTION

Wood is also extensively used as a source of chemicals for new materials and applications. It can be used as an efficient heat insulator in various interior spaces. Wood may be used as it is or after suitable chemical modification. New wood composite materials may be used as a source of fibre for paper, building and furniture works. They can also be used to shield radiation from nuclear sources. Under the International Union of Biological Nomenclature's naming system, every plant has a name with two parts; a genus and a species. Wood consists of cellulose 45%, hemi-cellulose 30%, lignin 20%, and extractives 5%.

Gamma attenuation coefficient is an important parameter for study of interaction of radiation with matter that gives us the fraction of energy absorbed or scattered [1, 2]. Some wood materials with a thin lead lining have earlier been tried for shielding X-ray facilities. So wood by

itself can be studied for its radiation shielding property. In this context the study of wood materials with regards to its ability to absorb radiation of different wavelength has given the scope of looking at different types of wood materials based on their hardness. Mass attenuation coefficient data for wood materials are useful for radiation shielding characteristics [3,4].
For this purposes the linear attenuation coefficient of few wood materials *Acacia nilotica (A.nilotica), Eucalyptus melliodora (E.melliodora), Mangifera indica (M.indica), Pterocarpus marsupium (P.marsupium), Tamarindus indica (T.indica*) plants of wood samples were used. In this study, an attempt is made to investigate the linear and mass attenuation coefficients based on sample thickness at 662, 1173 and 1332 keV for comparison with theoretical (XCOM data) values and also to verify sum rule.

MATERIALS AND METHODS

Sample Collection and Preparation

Dry wood samples were collected from the Nallamala forest area of the Kurnool district, Andhra Pradesh, India. In this works dry wood samples were used. The dimensions of wood samples are (2cm x 2cm x 1 cm, 2cm x 2cm x 2cm, 2cm x 2cm x 3cm, and 2cm x 2cm x 4cm).

Elemental composition of wood materials

The elemental composition of wood materials was determined by using inductively coupled plasma optical emission spectrometer (ICP-OES) method with the collaboration of DST-PURSE CENTRE, Sri Venkateswara University,Tirupati, Andhra Pradesh, India. Elemental composition of these materials with weight fractions are given in (Table 1).

Data analysis

The linear and mass attenuation coefficients of wood materials were measured by using the gamma spectrometer, consisting of an integral assembly of NaI(Tl) detector system which is connected to the 8K nuclear Multi Channel Analyser (MCA). Typical data collection times were about 10,000 sects for each measurement. A good geometry set up as shown in Fig.1 was designed and employed. The gamma spectra were analysed by GAMMA VISION software for the photo-peak areas [5]. A schematic view of the experimental system is given in Fig.2. The gamma ray sources are ^{137}Cs and ^{60}Co which produce gamma ray energy of 662, 1173 and 1332 keV, respectively. A typical gamma ray spectrum obtained with a ^{60}Co source, both attenuated and un-attenuated gamma at 1173 and 1332 keV is shown in Fig.3.
The linear attenuation coefficients have been evaluated comparing the attenuated intensity I and the unattenuated intensity, I_0, which are the measured count rates, with and without the absorber using the Beer-Lambert's formula

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

where I_0 is the number of counts recorded in the detector before attenuation, I is the number of counts recorded in the detector attenuation, μ is the linear attenuation coefficient (cm^{-1}), x is the thickness of the wood material in cm. [6].
Using the elemental composition of wood, mass attenuation coefficient of these samples were calculated with the help of computer program and data base developed by Berger and Hubbell [7] for all photon interactions following the sum-rule:

$$\frac{\mu}{\rho} = \Sigma_i W_i \left(\frac{\mu}{\rho}\right)_i \qquad (2)$$

Where $\left(\frac{\mu}{\rho}\right)_i$ is the photon mass attenuation coefficient for the individual elements in the compound and W_i is the fractional weight of the elements in the compound.

RESULTS AND DISCUSSION

Linear Attenuation Coefficient (μ) cm^{-1}

The experimentally determined values of the linear attenuation coefficients (μ) for *Acacia nilotica, Eucalyptus melliodora, Mangifera indica, Pterocarpus marsupium, and Tamarindus indica* for 662, 1173 and 1332 keV gamma energies are presented in (Table 2). It can be seen that *Acacia nilotica* has the highest attenuation coefficient for all energy regions. High attenuation coefficient wood is considered a very good absorber and a good quality material for radiation shielding and construction of building materials. *Eucalyptus* has the lowest attenuation coefficient compared to all other wood materials investigated. Lowest attenuation wood is considered a very bad absorber and a low quality material for radiation shielding. The linear attenuation coefficients decreased with the increasing gamma-ray energy.

Mass Attenuation Coefficient $\frac{\mu}{\rho}$ (cm^2/gm)

The values of the Z exponents for the photo effect of experimental results of mass attenuation coefficients are presented for three photon energies summarized in (Table 3). The measured values of $\frac{\mu}{\rho}$ for wood materials were compared with the theoretical values obtained from XCOM data base using the equation (2). These results are presented in [Table 4, 5, 6] for 662 keV, 1173 keV and 1332 keV respectively. It can be seen that the calculated and measured values of the mass attenuation coefficients are in good agreement for all the wood materials investigated. The Possible errors in the measurements presented are mainly due to statistical factors, non-uniformity of the absorber and here it comes to around 1.5%. Mass attenuation coefficient depends on the incident photon energy.

Table 1: Elemental composition of wood materials

Atomic Number (Z)	Elements	*A.nilotica*	*T. indica*	*P.marsupium*	*M. indica*	*E.melliodora*
1	H	4.702	4.575	4.435	4.561	4.516
5	B	0.510	0.355	0.454	1.277	0.280
6	C	46.530	46.666	45.702	47.802	46.801
7	N	2.431	2.466	2.530	2.426	2.420
8	O	45.665	45.737	46.730	43.766	45.861
11	Na	0.000	0.007	0.005	0.004	0.005
12	Mg	0.062	0.077	0.069	0.058	0.041
15	P	0.042	0.055	0.044	0.034	0.036
19	K	0.000	0.036	0.000	0.014	0.001
20	Ca	0.045	0.009	0.009	0.033	0.022
24	Cr	0.001	0.001	0.001	0.001	0.001
25	Mn	0.001	0.002	0.002	0.002	0.002
26	Fe	0.005	0.004	0.006	0.005	0.008
28	Ni	0.001	0.001	0.001	0.001	0.001
29	Cu	0.001	0.001	0.001	0.001	0.001
30	Zn	0.003	0.008	0.011	0.012	0.003
42	Mo	0.001	0.000	0.000	0.001	0.000
48	Cd	0.000	0.000	0.000	0.001	0.001
82	Pb	0.000	0.000	0.000	0.001	0.000

Table 2: Linear Attenuation coefficient for the wood materials at 662, 1173 and 1332 keV

Botanical name of wood	Density ρ(gm/cm³)	Linear Attenuation Coefficient (μ) cm^{-1}		
		662 keV	1173 keV	1332 keV
E.melliodora	0.818	0.065±0.001	0.055±0.001	0.041±0.001
M. indica	0.824	0.068±0.001	0.057±0.001	0.043±0.001
P. marsupium	0.886	0.071±0.001	0.059±0.001	0.045±0.001
T. indica	0.994	0.075±0.001	0.063±0.001	0.049±0.001
A. nilotica	1.007	0.078±0.011	0.065±0.001	0.052±0.001

Table 3: Experimental results for the mass attenuation coefficient of the wood samples

Botanical name of wood	Density ρ(gm/cm³)	Mass Attenuation Coefficient $\frac{\mu}{\rho}$ (cm²/gm)		
		662 keV	1173 keV	1332 keV
A.nilotica	1.007	0.077	0.064	0.051
T. indica	0.994	0.076	0.063	0.049
P.marsupium	0.886	0.080	0.066	0.051
M. indica	0.824	0.082	0.068	0.052
E.melliodora	0.818	0.079	0.067	0.050

Table 4: Comparison of experimental and theoretical (XCOM database) Mass Attenuation Coefficient (cm²/gm) of the wood samples at 662 keV

Botanical name of wood	Mass Attenuation Coefficient (cm²/gm)		
	662 keV		
	Experimental	Theoretical	% deviation
A.nilotica	0.077	0.084	-8.333
T. indica	0.076	0.083	-8.433
P.marsupium	0.080	0.083	-3.614
M. indica	0.082	0.081	1.234
E.melliodora	0.079	0.082	-3.658

Table 5: Comparison of experimental and theoretical (XCOM database) Mass Attenuation Coefficient (cm²/gm) of the wood samples at 1173 keV

Botanical name of wood	Mass Attenuation Coefficient (cm²/gm)		
	1173 keV		
	Experimental	Theoretical	% deviation
A.nilotica	0.064	0.065	-1.538
T. indica	0.063	0.065	-3.076
P.marsupium	0.066	0.064	3.125
M. indica	0.068	0.063	7.936
E.melliodora	0.067	0.064	4.687

Table 6: Comparison of experimental and theoretical (XCOM database) Mass Attenuation Coefficient (cm^2/gm) of the wood samples at 1332 keV

Botanical name of wood	Mass Attenuation Coefficient (cm^2/gm)		
	1332 keV		
	Experimental	Theoretical	% deviation
A.nilotica	0.051	0.054	-5.555
T. indica	0.049	0.053	-7.547
P.marsupium	0.051	0.053	-3.773
M. indica	0.052	0.052	0.000
E.melliodora	0.050	0.053	-5.660

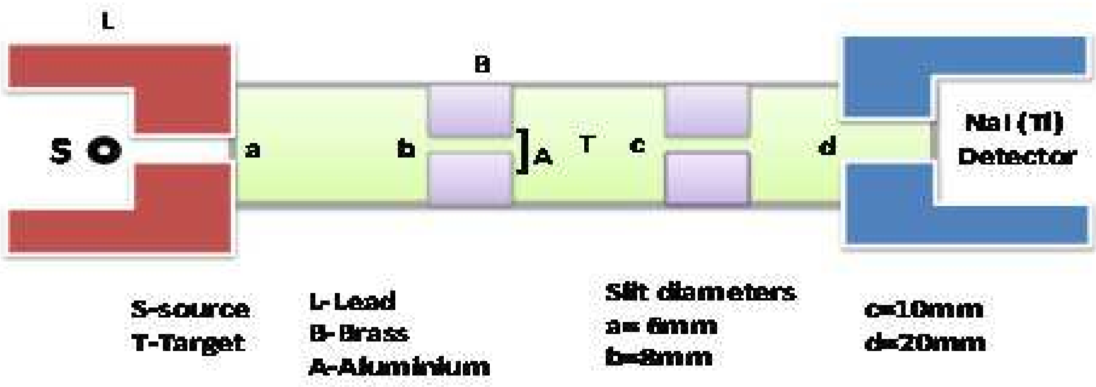

Fig.1. Experimental narrow beam good geometry set-up

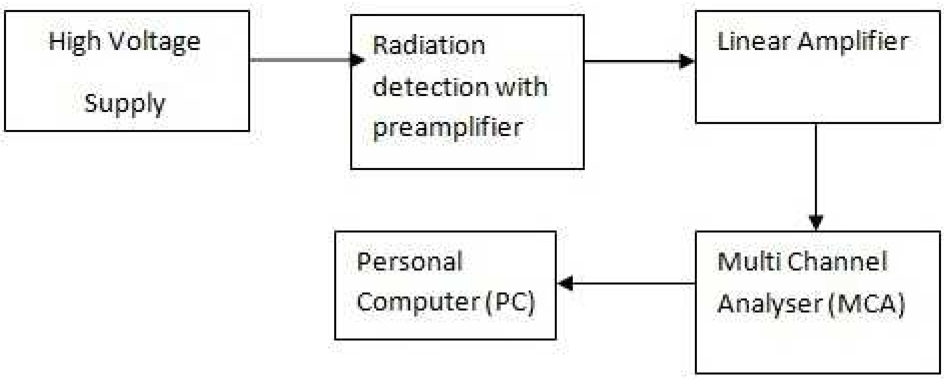

Fig.2. Schematic arrangements for Experimental system

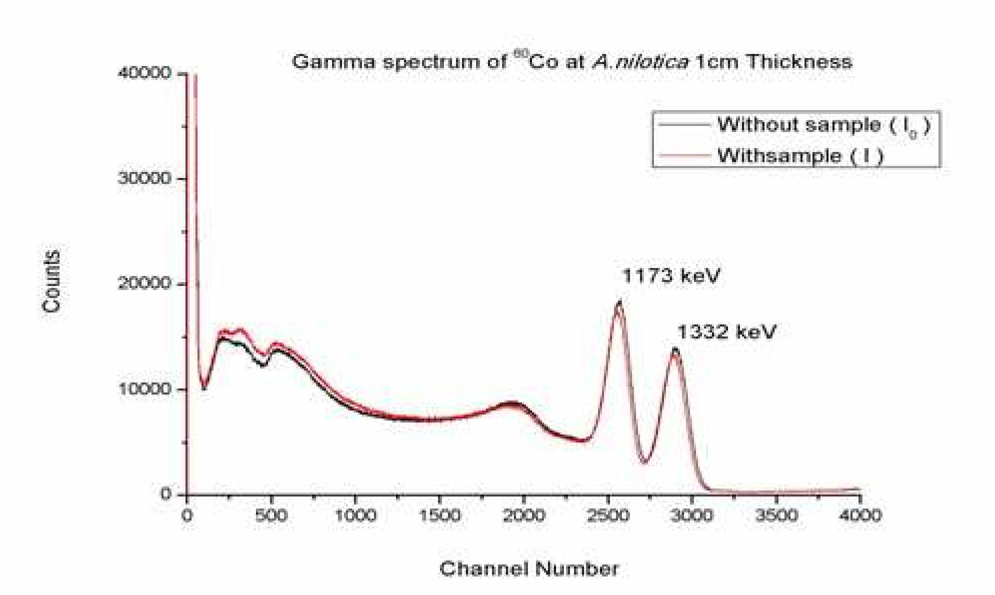

Fig.3. Gamma spectrum of ^{60}Co of *Acacia nilotica* wood at 1cm thickness

CONCLUSIONS

Mass attenuation coefficients depend on photon energy and chemical composition of the materials. It has been found that the mass attenuation coefficient decreases as photon energy increases. A good agreement between experimental and theoretical values can be seen. In all of the wood materials investigated in this study, High attenuation coefficient wood is considered a very good absorber and a good quality material for radiation shielding and construction of building materials. This type of study gives some insight about photon interactions with wood materials.

ACKNOWLEDGMENT: The authors wish to record their heartfelt gratitude to Bhagawan Sri Sathya Sai Baba for the beautiful facilities in the Nuclear Physics Research Laboratories of His University.

REFERENCES

[1] Charanjeet, S. C., Singh, T., Kumar, A., Mudahar, G.S. (2004) Energy and Chemical Composition dependence of mass attenuation coefficients of building materials. Ann.of Nucl.Energy.3, 1199-1205.
[2] Akkurt, I., Kilincarslan, S., Basyigit, C., Mavi, B., Akyildirim, H. (2009) Investigation of photon attenuation coefficient for Pumice. Int.J. of Phys.Scien 4-1,588-591.
[3] Kharita M .H., Takeyeddin M., Alnassar M., Yousef M. S. (2008) Development of Special Radiation shielding concretes using natural local materials and Evaluation of their Shielding characteristics, Prog.in Nuclear Energy 50:33- 36.
[4] Gil, A.M., Pascoal. (1999) Netosolid state NMR studies of wood and other Lignocellulosic materials, Ed. G. A. Webb. Annual Reports on NMR Spectroscopy 37:283.
[5] Gamma Vision -32. (1998) Ver 5.10.EG & G, ORTEC.
[6] Kaplan, I. (1972) Nuclear Physics (Addison-Wesley), New York
[7] Berger, M. J., Hubbell, J. H. (1987) XCOM:photon cross sections on a personal Computer, NBSIR87-3597, NBS, Washington, DC.