Annals of Industrial Technology

Research Article

Shielding Parameter Estimation of Some Woods

Elijah E. Onwoke[1], John N. Paul[2], Amaka A. Ogba[3], Rose A. Onoja[4], Raymond M. Agaku[5] and Saheed Yissa [6]

[1]Department of Medical Physics, Federal University of Health Sciences, Otukpo, Nigeria.
[2]Department of Human Anatomy, River State University, Port Harcourt, Nigeria.
[3]Department of Human Anatomy, River State University, Port Harcourt, Nigeria.
[4]Centre for Energy Research and Technology, Ahmadu Bello University, Zaria, Nigeria.
[5,6]Department of Physics, Benue State University, Makurdi, Nigeria.

Received 13 August 2024; Acceptance 6 September 2024; Published 11September 2024.

Abstract

Woods are readily available radiation shielding sources which compliment traditional shielding materials such as lead, concrete and steel. For this reason, parameter estimation of incorporated chemical substances in woods to enhance their usability in this regard is paramount. In this study, a total of five types of woods, namely, African Balsam, Gmelina, Tectona Grandis, Ironwood and Mahogany were collected from Agan forest located along Makurdi- Lafia Road, Makurdi, north central Nigeria. The wood samples were oven-dried with temperature range of 90 - 120℃ to remove water and the shielding parameter estimated. In this research, Mahogany has the highest radiation shielding capability of 0.4156cm $^{-1}$ and followed by Ironwood of 0.4084cm $^{-1}$ and while African Balsam has poor attenuation coefficient of 0.3909cm $^{-1}$ which is regarded as bad absorber of radiation. The results from this research demonstrate that radiation shielding is enhanced by wood of appreciable thickness. In this finding, the attenuation coefficient has maximum value for 21.73% water content and minimum value for 58.82% water content and as such justifies usability of woods as shielding materials owing to their availability, low cost and non-hazardous nature.

Keywords: Radiation, Wood, Shielding.

Introduction

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, high-energy medical equipment and wide range of its applications. In order to protect human from the hazardous effects of these radiations, metallic shields and non-metallic shields such as polymers are most often employed [1]. According to [2] radiation from high tech devices have the potential of causing damages to the human cell and as such, it is necessary to find some substances which can block and effectively absorb the radiation, especially gamma rays which have very high penetrating power as most substances cannot effectively absorb them. In order to ensure radiation protection and safety in different applications of ionizing radiation technology, certain measures must be put in place to reduce exposure levels to their minimum. These measures include, designing work schedule in a way that the safest possible distance is kept from the source. However, there

Correspondence to: Elijah Ebibi Onwoke, e-mail: ebibionwoke5@gmail.com

How to Cite: Onwoke et al. (2024). Shielding Parameter Estimation of Some Woods. *Annals of Industrial Technology,* **1(9**). DOI: 10.5281/zenodo.13748270

are limitations to the measures. Perhaps the most effective radiation protection is the use of shielding material between the worker and the source and also to reduce the radiation to where it is being applied without constituting danger to the general public [3].

Different authors,[4],[5],[6]and [7] have suggested that wood products of average thickness could be potentially useful in shielding hazardous emissions such as alpha, beta, neutron, X-rays and gamma radiations. Wood as a structural shielding material is comparatively less suitable than the widely acknowledged shielding materials earlier enumerated in attenuating ionizing radiations. To enhance its capability in this direction, appropriate chemical substances can be incorporated in its fabric. Wood of average thickness that has been fortified in this manner may be found suitable in the construction of x-ray shielding facilities with the added advantage of easy workability and light weight [8]. To this end, this research aims to estimate the attenuation coefficient value as a shielding parameter for different wood samples and as such, substitute the commonly used expensive and hazardous shielding materials.

Materials and Method

Sample collection. Five types of woods for this research work were collected from Agan forest. The wood samples were identified with their common names and include African Balsam (AB), Gmelina (GA), Mahogany (MH), Ironwood (IW) and Teak (TG).

Sample analysis. The samples were oven-dried with temperature range from 90 - 120℃. Samples were also weighed until constant weights were obtained which showed that the water was completely removed. The dried wood samples were further treated by soaking in water for twenty-one days to determine the effects of gamma radiation on wet wood and they were irradiated.

Physical Dimensions of the Wood. The samples were cut into a dimension such that the structural shielding can fit into the sample holder which it was rectangular form and was designed to maintain constant geometry during each counting operations. The sample was kept in between the source and the detector at 4cm distance interval. The volume of the samples for block or slice was determined by multiplying their length × breadth (Area) × thickness. For each sample, length, breadth and thickness were measured respectively while the density of the woods then was calculated using this expression.

$$\rho = \frac{m}{v} \quad (1)$$

Where ρ is density, v is volume and m is the mass of the wood samples.

Estimation methods

The shielding parameter of the aforementioned wood samples was estimated using a set of analytical expressions. The values obtained for the wood samples are a means to estimate the shielding capacity of each wood.

Determination of attenuation coefficient

The linear attenuation coefficient for each wood sample was measured separately by a transmission method. 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 [9]. A collimated $\gamma - ray$ beam was allowed to pass through the samples and the attenuated beam intensity was measured using Geiger Mueller Detector. For each thickness, series of counts were recorded from a detector to obtain the average count. The attenuation coefficient has been measured comparing the attenuated intensity I and the unattenuated intensity, I_o which are the measured count rates, with and without the absorber using the Beer-Lambert's formula [10]

$$I = I_o e^{-\mu x} \quad (2)$$

Where I_o 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}) and × is the thickness of the wood samples in cm. Taking natural logarithm of equation (2), we obtain

$$\mu x = ln\frac{I_o}{I} \tag{3}$$

Solving equation (3) for μ, we get:

$$\mu = \frac{1}{x} ln\frac{I_o}{I} \tag{4}$$

A background radiation was established by counting radiation beam intensity of the surrounding radiation, while the shutter of the source holder is closed. In order to avoid the irregularities in the counts of the background due to gas amplification in the counter, the counting was done several times before and after the experiment. The time for the counting was set for 900second which considered standard in determining the intensities of gamma –rays. The Radiation Counter was set at 820 Volt which is considered as a standard value.

Determination of wood water content. The water content in the wood can be determined by using the following relation [11]:

$$water\ content = \left[\frac{M_{wet} - M_{dry}}{M_{wet}}\right] \times 100 \tag{5}$$

Where M_{wet} is the weight of wet sample and M_{dry} is the weight of the completely dried sample. The sampled woods were weighed at wet state before drying them in an oven, and weigh again after some days to determine the variation of weight of the sample. After exposure of the drying sample, the sampled were soaked in water for twenty-one weeks before exposing them and the values for wet samples wood attenuation coefficient were determined.

Table1. Linear Attenuation Coefficient μ (cm^{-1}) of different wood species

Types of Wood	Slices	Co-60 Attenuation Coefficient	Mean	In(I_0/I)	Mean	Na-22 Attenuation Coefficient	Mean	In(I_0/I)	Mean
	AB_1	0.9313		0.3725		3.8512		1.5405	
	AB_2	0.4735		0.3788		1.9399		1.5519	
AFRICAN BALSAM(AB)	AB_3	0.3242	0.3909	0.3892	0.3905	1.3011	1.5862	1.5619	1.5629
	AB_4	0.2460		0.3936		0.9777		1.5643	
	AB_5	0.2008		0.4016		0.7861		1.5721	
	AB_6	0.1698		0.4071		0.6617		1.5867	
	GA_1	0.9215		0.3686		3.8741		1.5496	
GMELINA(GA)	GA_2	0.4779	0.3915	0.3823	0.3938	1.9399	1.6062	1.5519	1.5968
	GA_3	0.3250		0.3902		1.3115		1.5745	
	GA_4	0.2463		0.3941		0.9929		1.5887	

	GA_5	0.1993		0.3986		0.8201		1.6401	
	GA_6	0.1789		0.4290		0.6989		1.6760	
MAHOGANY(MH)	MH_1	0.9570		0.3828		4.0179		1.6072	
	MH_2	0.5064		0.4051		2.0120		1.6096	
	MH_3	0.3417	0.4156	0.4102	0.4254	1.3428	1.6518	1.6120	1.6301
	MH_4	0.2576		0.4122		1.0116		1.6186	
	MH_5	0.2297		0.4593		0.8226		1.6452	
	MH_6	0.2014		0.4830		0.7040		1.6882	
IRONWOOD(IW)	IW_I	0.9483		0.3793		3.9697		1.5879	
	IW_2	0.4945		0.3956		1.9888		1.5911	
	IW_3	0.3333		0.4001		1.3267		1.5927	
	IW_4	0.2544	0.4084	0.4071	0.4165	1.0157	1.6354	1.6252	1.6155
	IW_5	0.2289		0.4577		0.8234		1.6469	
	IW_6	0.1915		0.4593		0.6878		1.6494	
TECTONA GRANDIS(TG)	TG_1	0.9168		0.3667		3.9288		1.5715	
	TG_2	0.4989		0.3991		1.9819		1.5855	
	TG_3	0.3333	0.4034	0.4001	0.4133	1.3381	1.6254	1.6064	1.6072
	TG_4	0.2627		0.4203		1.0060		1.6096	
	TG_5	0.2179		0.4357		0.8064		1.6129	
	TG_6	0.1909		0.4577		0.6910		1.6571	

Table 2. Weight, water content and linear attenuation coefficient

Types of Wood	Weight of wood			Attenuation Coefficient μ (cm^{-1})	
	Dry	Wet	Water Content (%)	Co -60	Na-22
AFRICAN BALSAM(AB)	22.72	53.86	57.82	0.4020	0.7406
GMELINA(GA)	28.79	56.84	49.35	0.4165	1.2562
TECTONA GRANDIS(TG)	32.91	55.28	40.47	0.4212	1.3451

IRONWOOD(IW)	41.91	62.69	33.15	0.4257	1.5620
MAHOGANY(MH)	50.31	64.28	21.73	0.4391	1.6800

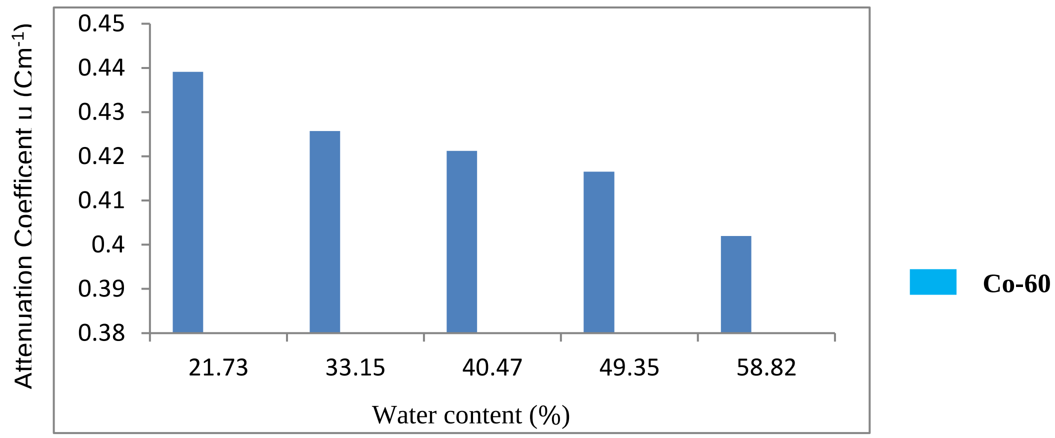

Figure 4.3a. Water content versus linear attenuation coefficient

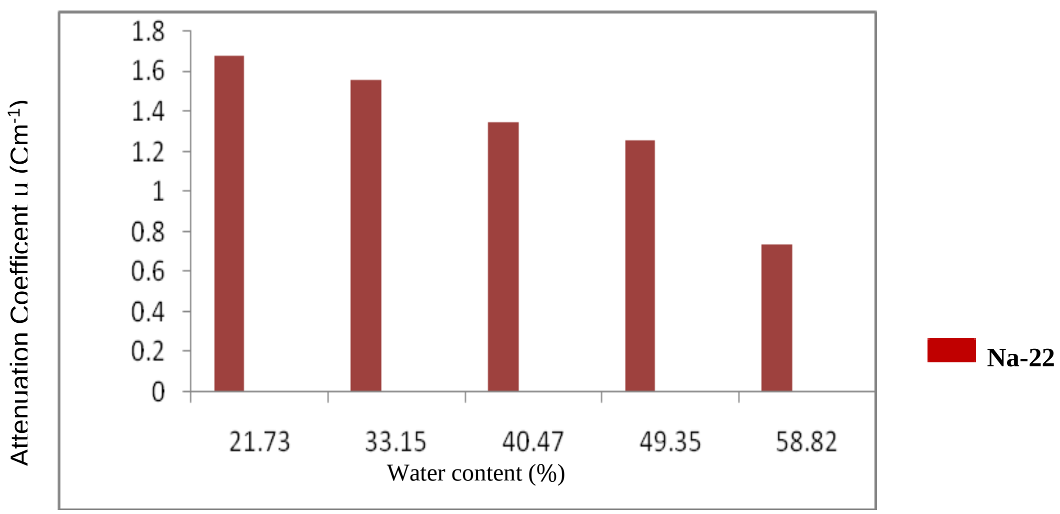

Figure 4.3b. Water content versus linear attenuation coefficient

Table 1 shows the results for the linear attenuation coefficient of the wood samples and in Table 2, the results for the weight, water content and linear attenuation coefficient of the wood samples are presented. This gives a comparison between the linear attenuation and water content. Figures 1-2 show the relationship between the linear attenuation coefficient and the water content of the wood samples. From these Figures, it is obvious that attenuation coefficient has maximum value for 21.73% water content and minimum value for 58.82% water content. This gives a variation between attenuation coefficient and wood thickness as shown in Table 1.

The results showed that there were significant values for linear attenuation coefficient due to transmission of gamma sources across the different wood thickness as depicted by values for water content. From these results, it is clear that the transmission reduced with increasing wood thickness.

Conclusion

The results from this research demonstrate that radiation shielding is enhanced by wood of appreciable thickness. In this study, the shielding parameter or attenuation coefficient has low value for wood with high thickness value and as such justifies usability of woods as shielding materials owing to their availability, cost and non-hazardous nature.

References

[1] Mackenzi, D (2010). ''A guide to the use of lead for Radiation Shielding''. Vol.1, pp3-6.

[2] Elias Sain, Zainal Abidin sulaiman, Anuar Ahmad and Hvsin Wagiran (1986). Determination of Effective Atomic Number of Rubber. *Pertanika 6(3); 95 -98*

[3] Ero F.A and Adebo B.A; (2012). Determination of γ −Radiation Shielding Charcteristics of some Tropical woods in West Nigeria. Department of Physics, University of Ibadan, Nigeria. Lead City University, Ibadan Nigeria. *International Archive of Applied Sciences and Technology, Vol.3 (2) June 2012;14-20. ISSN: 0976-4828*

[4] Bushbery, J.T; Seibert, J.A; Leidholdt, E. M, and Boone, J. M (2002). The Essential Physics of Medical Imaging. Lippincott Williams and Wilkins. London.

[5] AL- Bayati, AA (2002). Effect of Additive materials to concrete on γ-ray absorption coefficient. *An international journal (IJPA) Baghdad,* Department of Physics, College of Sciences, University of Baghdad, Baghdad, Iraq.

[6] Ogunkunle, A.T. J; Ojo, O.D and Oni, O.M. (2014). Anatomy and Specific Gravity of wood Sample from six Nigerian Tree Species in Relation to their Diagnosis X-ray Shielding Capabilities. *Journal of Natural Sciences Research*, Nigeria. Vol. 4.

[7] Rajasekhav. E and Jeevan kumar. R, (2014). Experimental Investigation of Gamma Radiation Shielding Characteristics of wood. Molecular Biophysical Laboratory. *International Journal of Humanities, Arts Medicine and Sciences (BEST: IJHAMS). ISSN 2348-0521, Vol 2.*

[8] National Council on Radiation Protection and Measurements, (1976). Structure Shielding design and evaluation for medical use of X-rays and Gamma rays of energies up to 10MeV. Bethesda, MD: NCRP: NCRP Report No49.

[9] Kaplan I, (1972). *Nuclear Physics*. Addison-wesley, New York.

[10] Chikkapa,U. (2013). Gamma ray Attenuation Study with varying Moisture Content of Clay Brick. *International Journal of Engineering Science Invention Vol.2, PP.35-38*

[11] Glass, Samuel V. and zelinka, Samuel L. (2010). Moisture Relation and physical properties of wood. Wood as an engineering material: chapter 4. Centennial edition. General technical report FPL; GTR-190. Madison W.I: US. Department of Agriculture, Forest Service, Forest Productions Laboratory, p.4.1 – 4.19