INVESTIGATION OF GAMMA RADIATION ATTENUATION CHARACTERISTICS OF SOME WOODS IN SOUTHERN NIGERIA

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ABSTRACT

The gamma radiation attenuation characteristics of ten wood samples sourced from southern Nigeria were investigated. The characteristics investigated were, density, linear attenuation coefficients, mass absorption attenuation coefficients and half value layer. The investigations were carried out using a gamma source (Cobalt – 60) and a Geiger Muller counter. The amount of radiation attenuated ranged between (0.058-0.045) count/sec with Red wood offering superior attenuation while Opepe offers the least, others in descending order of attenuation ability are Iroko, Cotton wood, Obeche, Pattern wood, Owen, Gum wood, Gmelina and Mahogany. Results could serve as a guide to diagnostic radiology facility owners on the type of wood that can enhance adequate attenuation of the secondary radiation within the operation room and protect the workers in the adjoining offices.

INTRODUCTION

Woods are widely used for the creation of shelter in the southern part of Nigeria either as building materials or for furniture making. They are used as doors with or without lining with lead in X-ray rooms, cubicles and in shielding other secondary radiation sources in diagnostic radiology facilities. Therefore it is necessary to investigate the attenuation characteristics of the different wood samples from within the environment. The information so obtained could guide the diagnostic radiology facility owners on the type of wood that would enhance adequate attenuation of the secondary radiation within the operation room and protect the workers in the adjoining offices, care givers and the general public from this secondary radiation. Secondly the use of these woods as doors in our residential building also enhances safety of its occupants against radiation fallout in case of any occurrence of nuclear radiation accident.

The need to find an alternative shielding material for gamma radiation and x-rays in medical and industrial application is because of the high cost of lead ; the conventional shielding material. It is known that an unregulated interaction of ionizing radiation with biological tissue causes deleterious effect because of the heat generated in the tissue due to the attenuation of the radiation by the layers of the tissue (NNRA, 2003). Consequently various materials have been investigated to be used for the shielding of gamma or x-rays, examples of such materials include, concrete (Samarin, 2013), marble, ceiling and gypsum board (Tuscharoen, *et al* 2013) etc.

The major aim of the use of ionizing radiation in medical practice is to obtain diagnostic information of the patient while keeping the dose of radiation as low as reasonably achievable. Shielding of radiation is one of the recommended radiation protection methods alongside keeping safe distance from radiation source and minimizing the period of interaction with the radiation source in diagnostic radiology procedure (ICRP, 1999). The dose (D) of radiation emitted from a radiation source obeys the inverse square law given in equation 1 where r is the distance between the source of radiation and the receptor

$$D = \frac{1}{r^2} \qquad 1$$

Equation 1 shows that the farther the receptor of this radiation from the source the lower the dose of radiation on the receptor. Therefore in radiation protection it is advisable for the workers and members of the public to keep safe distance away from the radiation source. Again the attenuation of gamma radiation in a good geometry is described using the attenuation law equation 2 (IAEA, 2003)

$$I = I_o e^{-\mu_m \rho x} \qquad 2$$

Where I is the intensity of radiation after shielding, I_o is the intensity of the incident radiation, x is the thickness of the shielding material. The linear attenuation coefficient μ is proportional to the density (ρ) such that

$$\mu = \mu_m \rho \qquad 3$$

μ_m and ρ are mass absorption coefficient and the density of the shielding material respectively Therefore from equation 2 we could have

$$\mu = -\left(\ln \frac{I}{I_o}\right)\frac{1}{x} \qquad 4$$

The degree of attenuation depends on the energy of the gamma source, atomic number Z of the material, (Elias *et al* 1983), density and the thickness of the material (IAEA 1996, ICRP, 1996). However, whenever intensities of the radiation are measured and μ_m is known, the thickness of the material required to reduce the radiation intensity to a given level could be calculated using equation 2. In addition, the Half Value Layer (HVL) which is defined as the thickness of the wood sample that could reduce the intensity of the incident radiation by half (HVL) is obtained from equation 5

$$HVL = \frac{\ln 2}{\mu} \qquad 5$$

The gamma radiation attenuation characteristics of the wood samples investigated were density (ρ), mass absorption coefficient (μ_m), HVL

MATERIALS AND METHOD

The ten wood samples investigated were purchased from different timber markets in Cross River, Akwa Ibom and Bayelsa States in Southern part of Nigeria. The wood samples were identified by the forestry/ wild life officer in Akwa Ibom State, Nigeria. The wood samples were cut into 25 cm by 25 cm and smoothen to fit into the designed holder to ensure constant geometry during the counting procedure. The wood samples were oven dried at 100 ^{o}c and weighed daily until their respective weight became constant showing that their water content has been removed. The samples were weighed with Mettler balance E- 2000, length, width and thickness were also measured and recorded. The experimental set up was such that the ^{60}Co gamma source and the Geiger Muller counter model J 2554-2 were separated by a distance of 13.0 cm with the sample holder placed mid way in between them. The background radiation intensity I_B was measured without the gamma source; the source intensity I_O was measured by pointing the Geiger Muller tube at 13.0 cm away from the source without the wood sample. The wood was placed at 6.5 cm in between the source and the counter and the transmitted radiation intensity I_I measured with the tube pointed at the centre of the wood sample. The transmitted radiation was recorded by a counter linked to the Geiger Muller tube. The reading from the counter was recorded in counts/seconds (C/s). Five readings were taken for each sample at 900 seconds per reading and mean recorded. The measured source and transmitted radiation intensities were corrected to obtain the actual values by subtracting the background radiation intensity from the measured values.

RESULT AND DISCUSSION

The identity of the 10 woods samples investigated are shown in Table 1 with their English and botanical names as identified by the forestry officer.

Table 1. Identity of the wood samples

S/N	English Name	Botanical Name
1	Iroko	*Milicia Excelsa*
2	Cotton Wood	*Ceiba Pentandra*
3	Red Wood	*Sequoia Sempervirens*
4	Pattern Wood	*Aistonia Boonei*
5	Gmelina	*Gemelina Arborea*
6	Gum Wood	*Brachystegia Laurenti*
7	African Mahogany	*Khaya Senegalensis*
8	Owen	*Quercus Camarienses*
9	African Yellow Wood	*Triplochiton Scleroxylon*
10	Opepe	*Nauclea Diderrichi*

The dimensions; length (L), breadth (B), thickness, (X) and mass, (M) of the wood samples, volume (V) and density of the woods samples are recorded in Table 2.

Table 2. Physical dimensions of the wood samples

S/N	Wood samples	L (cm)	B(cm)	X (cm)	V $(cm)^3$	M(g)	ρ (g/cm^3)
1	Iroko	25.3	25.2	1.3	828.8	492.4	0.59
2	Cotton wood	25.3	25.4	1.3	835.4	314.6	0.38
3	Red wood	25.4	25.4	1.3	838.7	756.6	0.90
4	Pattern wood	25.4	25.1	1.3	828.8	357.0	0.43
5	Gmelina	25.4	25.2	1.1	704.1	327.7	0.47
6	Gum wood	25.3	25.2	1.3	828.8	800.0	0.97
7	Mahogany	25.3	25.3	1.4	896.1	479.4	0.54
8	Owen	25.3	25.2	1.4	892.6	638.2	0.71
9	Obeche	25.4	25.2	1.2	768.1	313.3	0.41
10	Opepe	25.3	25.2	1.2	774.2	448.0	0.58

Table 2 shows that all the wood samples were approximately of the same cross sectional area but remarkable difference in their masses and densities. The density of the wood samples ranged between 0.38 g/cm^3 - 0.97g/cm^3 and mass ranged between 313.3g - 800.0g. Variation in the mass is due to the material content of the wood sample. This is responsible for the difference in the densities. Table 2 also shows variation in the volume of the wood as result of the variation in the thickness of the wood samples.

Table 3 Mean measured intensity, calculated linear attenuation coefficient, half value layer, mass absorption coefficient (μ_m) and amount of radiation attenuated (ΔI)

I_B = 0.490 C/s, I_O = 0.550 C/s, actual I_B = 0. 06 c/s $(\Delta I = I_o - I_1)$

Wood sample	I_1 (C/s)	actual I_1 (C/s)	$\ln \frac{I_1}{I_0}$	$\mu(cm)^{-1}$	HVL (cm)	μ_m Cm^2/g	(ΔI) (C/s)
Iroko	0.494	0.04	-0.41	0.31	2.24	0.53	0.056
Cotton wood	0.495	0.05	-0.18	0.14	4.95	0.38	0.055
Red wood	0.492	0.02	-1.10	0.88	0.79	0.98	0.058
Pattern wood	0.499	0.09	0.41	-0.33	2.10	0.77	0.051
Gmelina	0.497	0.07	0.15	-0.15	4.62	0.32	0.053
Gum wood	0.499	0.09	0.41	-0.33	2.10	0.34	0.051
Mahogany	0.505	0.15	0.92	-0.66	1.05	1.22	0.045
Owen	0.499	0.09	0.41	0.31	2.24	0.44	0.051
Obeche	0.495	0.05	-0.18	0.15	4.62	0.37	0.055
Opepe	0.505	0.15	0.92	-0.77	0.90	1.21	0.045

The minus sign in some of the values of the attenuation coefficient in Table 3 shows that the actual intensity of the transmitted radiation is far lower than the actual intensity of the incident radiation. Figure 1, shows the percentage linear attenuation coefficients of the different wood samples investigated.

Table 4. Summary of the attenuation characteristics of the wood samples

S/N	Wood samples	μ (cm)$^{-1}$	μ_m (cm^2/g)	HVL (cm)	$\rho\left(g/(cm)^3\right)$
1	Iroko	0.31	0.53	2.24	0.59
2	Cotton wood	0.14	0.38	4.95	0.38
3	Red wood	0.88	0.98	0.79	0.90
4	Pattern wood	-0.31	0.77	2.10	0.43
5	Gmelina	-0.15	0.32	4.62	0.47
6	Gum wood	0.33	0.34	2.10	0.97
7	Mahogany	-0.66	1.22	1.05	0.54
8	Owen	0.31	0.44	2.24	0.71
9	Obeche	0.15	0.37	4.67	0.41
10	Opepe	-0.77	1.21	0.90	0.58

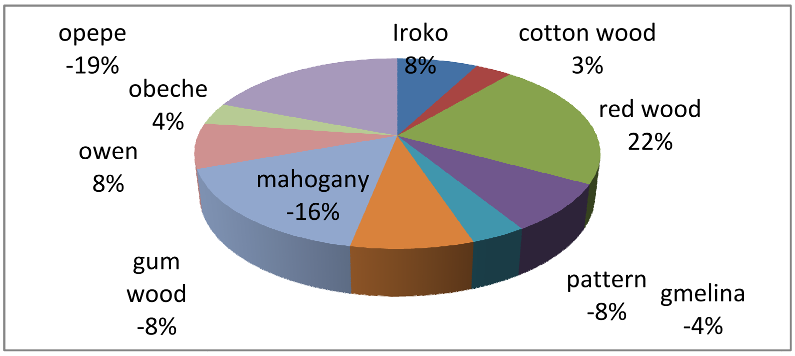

Fig 1.: Percentage of linear attenuation coefficients per wood sample

The arrangement of the wood samples in descending order of percentage linear attenuation coefficient shows red wood as the highest with 22% followed by Iroko, Owen, Obeche and Cotton wood as the lowest with 4 %. The comparison of μ_m for the different wood samples (Fig. 2) shows that red wood has the highest mass absorption attenuation coefficient (μ_m) and Gmelina with the lowest μ_m. The μ_m is known to be dependent on the elemental composition of the material, that is, it depends on the density of the wood samples, hence the reason for the variations in mass absorption attenuation coefficient for the woods even within woods of the same thickness.

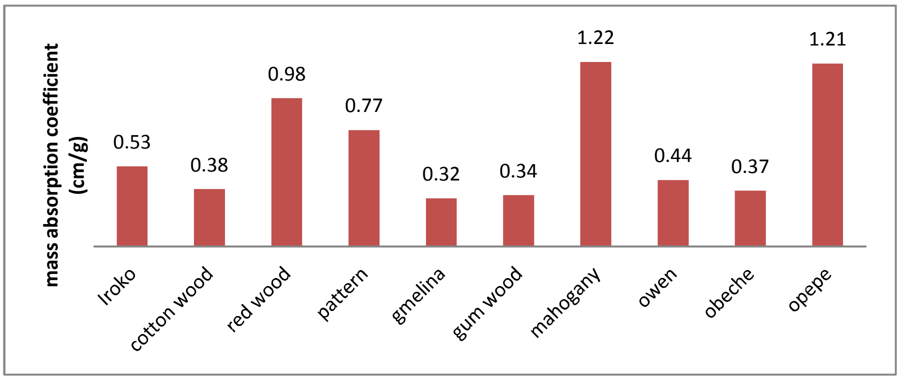

Fig. 2. Comparison of mass absorption coefficient of the samples

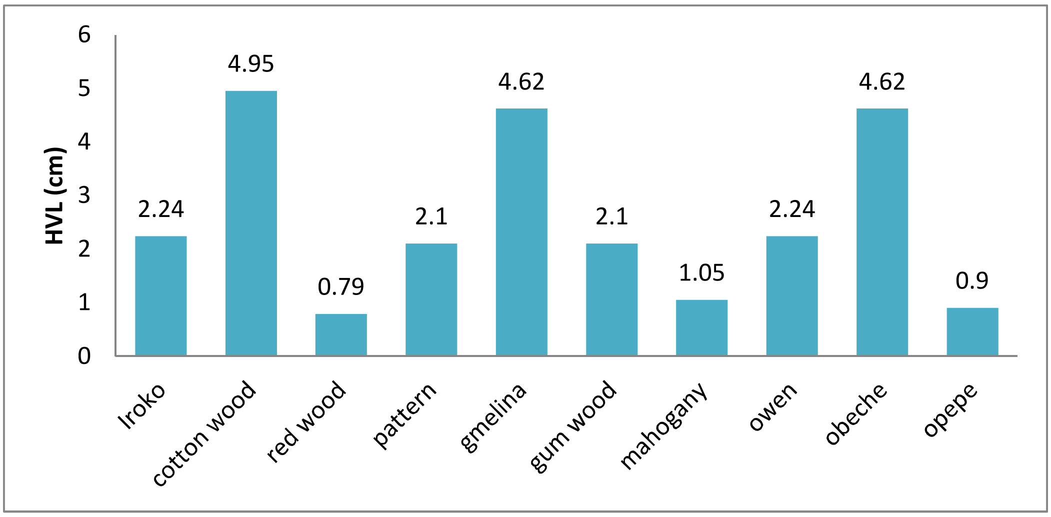

Fig 3: Comparison of half value layer of the wood samples

The known mass absorption attenuation coefficient and the density of the wood samples were used in calculating the thickness of the wood sample that could reduce the incident radiation by 50% (Table 2). The comparison of the HVL for the samples is shown in Fig. 3 with cotton wood having the highest HVL and red wood with the least. From equation 2, for a given thickness of the shielding material, the ones with high density, high attenuation coefficient and low HVL offer superior attenuation than the materials with low density and high HVL (Ero and Adebo, 2012).

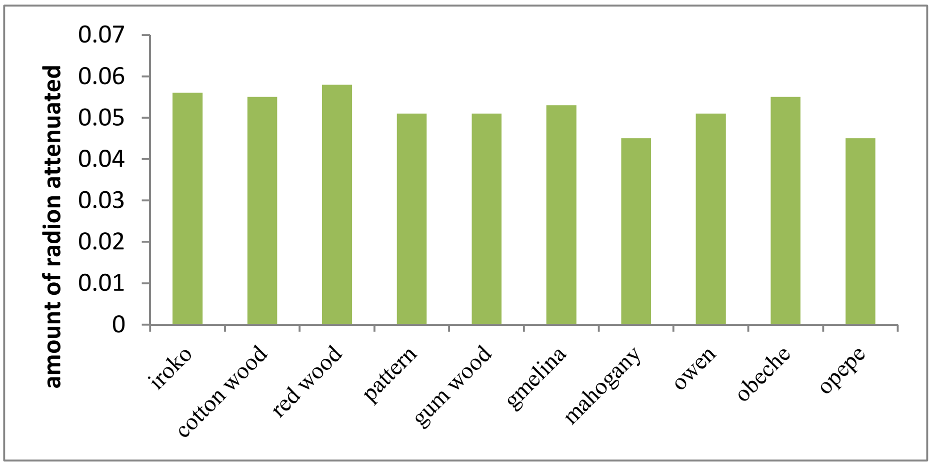

Fig 4. Comparison of woods samples in terms of amount of radiation attenuated

The radiation absorption ability of the different wood samples is measured in term of the amount of radiation absorbed by the woods after interaction with the radiation. This is measured from the difference between the intensity of the incident radiation and the intensity of the transmitted radiation. Analysis of Figure 4 in terms of woods of the same thickness reveals that for woods of thickness of 1.3 cm, red wood has the highest attenuation ability, followed by Iroko, Cotton wood, Pattern wood and Gum wood. For wood samples of thickness of 1.4 cm, Owen absorbed better than mahogany and finally Obeche attenuates better than Opepe in 1.2 cm category.

It has been reported that the best attenuation is obtained from woods with the highest linear attenuation coefficient, high density and lowest half value layer (Ero and Adebo 2012). From the results obtained it could be observed that the best parameter of comparison of the attenuation ability is comparing the quantity of radiation attenuated (ΔI) by the different wood samples as other parameters are density dependent. In summary, red wood offers superior attenuation while opepe offers the least, others in descending order of attenuation ability are Iroko, Cotton wood, Obeche, Pattern wood, Owen, Gum wood, Gmelina and Mahogany.

CONCLUSION

The investigation carried out shows red wood offering superior attenuation to gamma radiation while Opepe offers the least, others in descending order of attenuation ability are Iroko, Cotton wood, Obeche, Pattern wood, Owen, Gum wood, Gmelina and Mahogany. From the results it is better to measure the ability of attenuation from the real measured parameter, the amount of radiation attenuated after interaction of the gamma radiation with the wood samples.

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