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Original Article

Determination of γ - Radiation Shielding Characteristics of some Woods in Western Nigeria

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ABSTRACT

This study compares the shielding characteristics of twenty-two tropical woods by using gamma scintillation detection method.

The intensities of the emergent radiation were measured, when each of these woods were placed between a scintillation detector and a standard radioactive source. Analysis of result obtained shows an appreciable evidence of radiation attenuation due to the changes in the chemical composition of the woods and the dependence of the attenuation coefficient on energy and densities of these woods. The descending order of attenuation coefficient determined for each wood type are ; Ayin, Oro, Anuje, Ako, Asunrun, Apa-igbo Gedu, Agbonyin , Opepe Oganwo, Iroko Odogi , Ayo, Ayunre , Afara , Omo, Melania, Akomu, Arere, Pine, Araba. For a constant energy of 0.101MeV, the attenuation coefficient are 0.190cm^{-1}, 0.165cm^{-1}, 0.163cm^{-1}, 0.156cm^{-1}, 0.149cm^{-1}, 0.143cm^{-1}, 0.133cm^{-1}, 0.132cm^{-1}, 0.127cm^{-1}, 0-124cm^{-1}, 0.085cm^{-1}0-123cm^{-1}, 0-122cm^{-1}, 0.113cm^{-1},0.101cm^{-1}, 0.088cm^{-1},0.087cm^{-1}, 0.086cm^{-1}, 0-082cm^{-1} respectively.

The wood in descending order of dependence of attenuation coefficient on density are : Ayin,Oro, Anunje,Ako,Asunrun,Apa-Igbo, Gedu, Agbonyin, Opepe, Oganwo, Iroko, Odogi, Ijebo,
Ayo, Ayunre, Afara, Omo, Melania, Akomu, Arere, Pine and Araba. The half value layer shows the thickness at various energy regions.

Result shows that attenuation coefficient depends on the energy of incident photons and the nature of the absorbing woods.

Key words: *Gamma Scintillation, Radiation, Attenuation Coefficient, Half Value Layer (HVL), Density*

INTRODUCTION

Gamma rays (γ-rays) are electromagnetic waves. Their wavelengths run from about 10^{-10}m to well below 10^{-14}m, with corresponding frequency range from 3×10^{18}Hz to more than 3×10^{22}Hz. γ-rays are produced by many radioactive substances. They can also be found in nuclear reactors and in cosmic radiation. There are many useful applications of gamma ray such as radiotherapy, medical tracer and sterilization. Nevertheless when γ-rays are absorbed by a living organism (e.g. human), they may cause serious effects. Therefore, it is necessary to find out some substances that can effectively absorb and block γ-rays. Gamma radiation from radionuclides, such as 40K and the 232Th and 238U series and their decay products, represents the main external source of irradiation to the human body [1] .

The penetrating power of γ-rays, however, is very high so that most substances cannot effectively absorb them.

In order to ensure radiation safety in the various application of ionizing radiation technology certain procedures must be put in place to reserve exposure levels to their maximum. These procedures include, designing work schedule in a way that the safest possible distance is kept from the source. However, there are limitations to the above procedures.

Perhaps the most effective radiation protection is the use of shielding materials between the workers and the source and also to curtail the radiation to where it is being applied without constituting danger to the general public.

A shield material is expected to have high gamma ray attenuation coefficient in orders that a small thickness will produce significant reduction in intensity. The practice for instance is to use lead (Pb) lining on doors of X-rays rooms. However, the observation is that a large number of X-rays centres use wooden doors of different thickness without Pb lining. The aim of his project is to answer the question “how safe are these wooden doors”.

This was done by collecting samples of wood commonly used in Nigeria and determining their gamma attenuation characteristics. By comparing this, especially at low gamma ray energies with

known characteristic of lead one can judge their suitability or otherwise of these woods for shielding purposes.

THEORY

Attenuation

When gamma rays or x-rays of intensity I are made to pass through a material thickness dx the resulting reduction dI in the intensity is termed attenuation. This reduction dI is proportional to both I and dx, and is expressed as

$dl \ \alpha \ Idx$ … … … … … … … … … … … 1.0

$dI = -\mu Idx$ … … … … … … … … … . . .2.0

Where is the linear attenuation coefficient, which depends on the absorbing material and the energy of the gamma rays.

Integrating equation 2.0 results [4] to ;

$I = I_0 e^{-\mu x}$ … … … … … … … 3.0

Equation 3.0 is called attenuation equation. The attenuated intensity in a good geometry experiment can be described by the Lambert Equation I= I_0 *exp(-μ x)* where I is radiation intensity after attenuation, I is un-attenuated radiation intensity (counts/s): μ is the linear attenuation coefficient and x is the absorber thickness (cm). Since the beam intensity attenuation is due to the interaction of photons with electrons of atoms of the object the attenuation coefficient is therefore dependent upon atomic number of the atoms and energy of the photons, i.e. the linear attenuation coefficient is a function of the atomic number, Z, and [2, 3] energy, E, or μ(Z,E).

The initial radiation intensity I_0 decreases exponentially with the thickness of material x. the u is due to all the effects of radiation interaction with matter.

Linear attenuation coefficient u is always proportional to the density of the materials. This is

$\mu \ \alpha \ \rho$ … … … … … … … … … … … … 4.0

$\mu = \mu_m \rho$ … … … … … … … … . .5.0

where μ_m is called mass attenuation coefficient. For some purpose it is useful to use atomic attenuation, μ_a. This is the fraction of the incident gamma beam that is attenuated by a single atom. It is also the probability of a single atom interacting with one of the photons in the beam. It is defined as

$\mu_a = \frac{\mu}{N}$ … … … … … … … … … … .6.0

Where N is the number of absorber atoms per unit volume. The atomic linear attenuation coefficient N_a is measure in cm^2 a dimension of area. Hence it represents the area of interaction of the incident beam or the cross section of the absorber measured in barns.

It has been found out that the attenuation coefficient increases linearly with an increase in wood density. The attenuation coefficient of heavy hard woods is higher than that of medium and light hardwoods.

When radiation passes through matter, it dissipates its energy in the ionization and excitation of the molecules of the materials, either directly as we have for charged particles or indirectly as we have far neutrons and photons. Radiation detection methods are based on measurable physical and chemical changes resulting from these ionizations and excitations. However, it is difficult to distinguish between instruments based on either of these energy transfer mechanisms as both are almost simultaneous even though one is predominant over a certain energy range and in a particular physical state of the interacting medium.

Essentially, a radiation detection method involves the use of a medium that is capable of absorbing the radiation energy and converting it to a form measured. From the point of view of the forms of these observable effects of ionization and excitation radiation detectors can be divided into three broad categories, namely: counters, visualization detectors and dosimeters.

METHODOLOGY

22 Wood samples used in this work were collected from Ibadan, Ijebu – Ode and Benin – city which are the major centres for timber industries in Nigeria. The sizes of samples collected are in the range of 30cm x 30cm. A total of twenty-two samples were collected and identified with the assistance of Forestry and Wild life Department of the University of Ibadan.

The samples were cut into a dimension of 14cm x 12cm such that they could fit into the sample holder which has been designed to ensure constant geometry during each counting operations. The holder has been designed and constructed to keep the wood sample in-between the source and the detector at a distance of 6.5cm from the 7.6cm x 7.6cm NaI (TI) crystal surface detector.
The first treatment given to the wood samples was to season them by drying for several days in an oven operating at a temperature of 100^0C. These samples were weighed each day until their weights became constant, showing that the water content has been removed.
The determination of the intensities of gamma – emitter is performed in a box built using lead blocks of 5cm thickness, containing a 76cm x 76cm NaI (TI) detector coupled to a Canberra series 10 multichannel Analyzer (MCA) system. This was employed because of its high detection efficiency for gamma – rays.
The lead blocks are to shield away background radiations from the environment. The constructed sample holder was placed on the NaI (TL), crystal detector with the Thorium -232 source suspended by a cardboard 6.5cm away from the detector. The time for the counting was set for 1000 second which is considered adequate in determining the intensities of gamma – rays.
Seven regions of interest (ROI) were defined, after the initial intensity I_0, had been taken. That is, when no sample was placed in the samples holder. This was followed by recording the intensity I of various wood samples when placed between the source and the detector.

Table 1: Wood Species Collected

S/N	Botanical Names	Local Names	Cities
1.	*Anogeisus leiocarpus*	Ayin	Ibadan
2.	*Nesogordonia papverifera*	Oro	Ibadan
3.	*Entandrophragma microphyllum*	Anunje (Local mahogany)	Ijebu-ode
4.	*Brachystagia eurycoma*	Ako	Ibadan
5.	*Cassia alata*	Asunrun (Cassia)	Ibadan
6.	*Afzelia Africana*	Apa-Igbo	Benin-City
7.	*Khaya grandifoliala*	Gedu (Teak)	Ibadan
8.	*Piptadenistrum Africana*	Agbonyin	Ibadan
9.	*Nanclea diderrehii*	Opepe	Benin-City
10.	*Khaya ivorensis*	Oganwo	Benin-City
11.	*Chlorophora excels*	Iroko	Ibadan
12.	*Masonia altissima*	Odogi (Mesonia)	Ibadan
13.	*Entandrophragma angolense*	Ijebo	Ijebu-Ode
14.	*Altium sativum*	Ayo	Ibadan
15.	*Albizia zygia*	Ayunre	Ijebu-Ode
16.	*Terminalia superb*	Afara	Ijebu-Ode
17.	*Cordial millenii*	Omo	Ijebu-Ode
18.	*Melaina*	Melaina	Benin-City
19.	*Pycnanthus angolensis,*	Akomu	Ijebu-Ode
20.	*Triplochitons scleroxylon*	Arere	Ibadan
21.	*Pine*	Pine	Ibadan
22.	*Ceiba pentradra*	Araba	Ibadan

Table 2: Readings From Multichannel Analyser (MCA)

Intensity of wood	0.101Mev	0.265Mev	0.627Mev	0.955Mev	1.646Mev	2.645Mev	3.212Mev
Ayin	2437	222	2301	4756	266	964	12
Oro	2468	189	2224	2224	264	950	10
Arunje	2887	458	2626	4711	273	1017	21
Ako	2668	300	2413	4961	268	981	15
Asunrun	2789	388	2525	4841	270	1000	18
Apa-Igbo	2928	510	2669	4912	273	1023	22
Gedu	2590	283	2345	499 7	265	968	13
Agbeyin	2722	312	2455	4822	268	991	16
Opepe	2049	88	1827	4884	249	874	5
Oganwo	2620	319	2378	4502	265	976	14
Iroko	2659	351	2433	4876	266	984	16
Odogi	2388	210	2187	4905	259	940	11

Ijebu	2732	446	2506	4782	268	996	18
Ayo	2621	375	2427	4942	265	980	16
Ayunre	2804	520	2609	5043	270	1010	22
Afara	2758	479	2513	5039	267	1003	20
Omo	2730	636	2628	5122	270	1029	24
Melaina	2925	631	2541	5097	267	1030	22
Akomu	3040	760	2673	5163	271	1059	27
Arere	3055	784	2706	5203	271	1060	28
Pine	3421	1309	3082	5323	282	1105	45
Araba	3170	921	2826	5283	276	1073	35

Table 3: Wood Thickness

S/N	Name	Thickness (cm)
1.	Ayin	2.3
2.	Oro	2.57
3.	Arunje	1.64
4.	Ako	2.22
5.	Asunrun	2.00
6.	Apa-Igbo	1.70
7.	Gedu	2.63
8.	Agbeyin	2.38
9.	Opepe	2.59
10.	Oganwo	2.76
11.	Iroko	2.67
12.	Odogi	2.60
13.	Ijebu	2.60
14.	Ayo	2.96
15.	Ayunre	2.43
16.	Afara	2.77
17.	Omo	2.50
18.	Melaina	2.89
19.	Akomu	2.48
20.	Arere	2.45
21.	Pine	1.15
22.	Araba	2.12

Table 4: Result of Calculations of Attenuation Coefficient μ (cm^{-1})

S/N	Botanical Name	0.101Mev	0.265Mev	0.627Mev	0.955Mev	1.64Mev	2.645Mev	3.212Mev
1.	*Anogeisus leiocarpus (Ayin)*	0.19	0.960	0.175	0.054	0.038	0.075	0.724
2.	*Nesogordonia papverifea (Oro)*	0.165	0.922	0.17	0.052	0.037	0.073	0.710
3.	*Entandrophragma Microphyllum (Anunje)*	0.163	0.904	0.165	0.05	0.037	0.073	0.689
4.	*Brachystagia eurycoma (Ako)*	0.156	0.859	0.16	0.048	0.036	0.07	0.668
5.	*Cassia Alata (Asunlun)*	0.151	0.825	0.155	0.046	0.035	0.068	0.647
6.	*Afzelia Africana (Apa-Igbo)*	0.149	0.809	0.15	0.044	0.035	0.067	0.626
7.	*Khaya grandifoliola (Gedu)*	0.143	0.747	0.146	0.042	0.034	0.064	0.605
8.	*Piptadenistrum Africana (Agboyin)*	0.137	0.710	0.142	0.041	0.033	0.061	0.584
9.	*Nanclea diderrehii (Opepe)*	0.133	0.682	0.138	0.039	0.033	0.059	0.563
10.	*Khaya ivorensis (Oganwo)*	0.132	0.668	0.134	0.036	0.033	0.058	0.542
11.	*Chlorophora excels (Iroko)*	0.131	0.655	0.13	0.035	0.032	0.057	0.521
12.	*Masonia altissima*	0.l27	0.629	0.26	0.033	0.031	0.055	0.500

	(Odogi)							
13.	*Entandrophragma angolense (Ijebo)*	0.124	0.581	0.122	0.03	0.031	0.054	0.479
14.	*Altium sativum (Ayo)*	0.123	0.569	0.118	0.029	0.031	0.053	0.458
15.	*Albizia zygia (Ayunre)*	0.122	0.558	0.114	0.027	0.03	0.052	0.437
16.	*Terminalia superb (Afara)*	0.113	0.519	0.111	0.024	0.03	0.048	0.416
17.	*Cordial millenii (Omo)*	0.101	0.462	0.108	0.02	0.029	0.043	0.396
18.	*Melaina (Melaina)*	0.088	0.402	0.105	0.019	0.028	0.037	0.374
19.	*Pycnanthus angolensis (Akomu)*	0.087	0.394	0.102	0.017	0.028	0.032	0.353
20.	*Triplochitons sclexylon (Arere)*	0.086	0.386	0.099	0.014	0.027	0.032	0.332
21.	*Pine (Pine)*	0.085	0.378	0.096	0.01	0.024	0.032	0.311
22.	*Ceiba pentradra (Araba)*	0.082	0.370	0.093	0.009	0.024	0.031	0.290

Table 5: Dimensions and Density of Wood

S/N	Botanical/Local Names	Length (cm)	Breadth (cm)	Thickness (cm)	Mass (g)	Volume (cm)	Density (g/cm³)
1.	Anogeisus leiocarpus (Ayin)	14.62	11.5	2.3	355	388.38	0.91
2.	Nesogordonia papverifea (Oro)	14.93	11.05	2.57	335	423.99	0.79
3.	Entandrophragma Microphyllum (Anunje)	13.9	11.5	1.64	206	262.15	0.78
4.	Brachystagia eurycoma (Ako)	15.67	11.13	2.22	209	387.15	0.75
5.	Cassia Alata (Asunlun)	14.24	11.53	2	240	328.37	0.73
6.	Afzelia Africana (Apa-Igbo)	15.03	11.36	1.7	210	290.26	0.72
7.	Khaya grandifoliola (Gedu)	14.14	11.5	2.63	295	427.66	0.69
8.	Piptadenistrum Africana (Agboyin)	14.56	11.15	2.38	255	386.38	0.66
9.	Nanclea diderrehii (Opepe)	14.62	9.7	4.59	245	695.45	0.64
10.	Khaya ivorensis (Oganwo)	14.72	11.33	2.76	290	461.81	0.63
11.	Chlorophora excels (Iroko)	14.6	11.17	2.67	270	435.43	0.62
12.	Masonia altissima (Odogi)	15.03	11.4	3.6	370	616.83	0.6
13.	Entandrophragma angolense (Ijebo)	15.07	11	2.6	258	431	0.6
14.	Altium sativum (Ayo)	14.96	10.78	2.96	280	477.36	0.59
15.	Albizia zygia (Ayunre)	15.06	10.87	2.43	230	397.8	0.58
16.	Terminalia superb (Afara)	14.94	11.1	2.77	250	459.36	0.54
17.	Cordial millenii (Omo)	14.94	10.77	2.5	195	402.26	0.48
18.	Melaina (Melaina)	14.53	11.5	2.89	205	482.9	0.42
19.	Pycnanthus angolensis (Akomu)	14.83	11.38	2.48	165	418.25	0.39
20.	Triplochitons sclexylon (Arere)	14.9	11.3	2.45	160	412.51	0.39
21.	Pine (Pine)	15.07	11.34	1.15	65	196.53	0.33
22.	Ceiba pentradra (Araba)	14.54	11.46	2.12	115	353.25	0.33

Table 8: Result of Calculation of Half Value Layer (HVL) (cm)

S/N	Botanical /Local/Know Name	0.101Mev	0.265Mev	0.627Mev	0.955Mev	1.64Mev	2.645Mev	3.212Mev
1.	Anogeisus leiocarpus (Ayin)	3.658	0.722	3.961	12.836	18.241	9.242	0.957
2.	Nesogordonia papverifea (Oro)	4.201	0.752	4.077	13.33	18.734	9.595	0.976
3.	EntandrophragmaMicrophyllum (Anunje)	4.252	0.767	4.201	13.863	18.734	9.495	1.006
4.	Brachystagia eurycoma (Ako)	4.443	0.807	4.332	14.441	19.254	9.902	1.038
5.	Cassia Alata (Asunlun)	4.59	0.84	4.472	15.068	19.804	10.193	1.071
6.	Afzelia Africana (Apa-Igbo)	4.652	0.857	4.621	15.755	19.804	10.345	1.107
7.	Khaya grandifoliola (Gedu)	4.847	0.928	4.748	16.504	20.387	10.83	1.146
8.	Piptadenistrum Africana (Agboyin)	5.059	0.976	4.881	16.906	21.004	11.363	1.187
9.	Nanclea diderrehii (Opepe)	5.212	1.016	5.023	17.773	21.004	11.748	1.231
10.	Khaya ivorensis (Oganwo)	5.251	1.047	5.173	19.254	21.004	11.951	1.279
11.	Chlorophora excels (Iroko)	5.291	1.058	5.332	19.804	21.661	12.16	1.33
12.	Masonia altissima (Odogi)	5.458	1.102	5.501	21.004	22.36	12.603	1.386
13.	Entandrophragma angolense (Ijebo)	5.59	1.193	5.682	23.105	22.36	12.836	1.447

14.	Altium sativum (Ayo)	5.635	1.218	5.874	23.902	22.36	13.078	1.513
15.	Albizia zygia (Ayunre)	5.682	1.242	6.08	25.672	23.105	13.33	1.586
16.	Terminalia superb (Afara)	6.134	1.336	6.245	28.888	23.105	14.441	1.666
17.	Cordial millenii (Omo)	6.862	1.5	6.418	34.657	23.902	16.12	1.75
18.	Melaina (Melaina)	7.877	1.724	6.601	36.481	24.755	18.734	1.853
19.	Pycnanthus angolensis (Akomu)	7.967	1.759	6.796	40.773	24.755	21.661	1.964
20.	Triplochitons sclexylon (Arere)	8.06	1.796	7.001	49.511	25.672	21.661	2.088
21.	Pine (Pine)	8.15	1.834	7.22	69.315	28.881	21.661	2.229
22.	Ceiba pentradra (Araba)	8.453	1.873	7.453	77.016	28.881	22.36	2.39

RESULT AND DISCUSSION

The graph in figure 2 shows that, attenuation coefficient depends on the energy of incident photons and the nature of the absorbing woods. A different exponential curve for the various woods collected shows that attenuation coefficient decreases with increasing energy. Therefore, it can be inferred that high energy photons are not easily attenuated while low ones are prone to easy attenuation.

A close look of the attenuation coefficient against energy graph in figure 2 revealed, that, Ayin (Anogeissus Leiocarpus) has the highest attenuation ability when all energy regions are considered. The curves are arranged in their descending order of attenuation ability is as follows: Ayin, Oro, Anunje, Ako, Asunrun, Apa-igbo, Gbedu, Agbonyin, Opepe, Oganwo, Iroko, Odogi, Ijebu, Ayo, Ayunre, Afara, Omo, Melaina, Akomu, Arere, Pine and Araba. As a result of high attenuation coefficient; Ayin is considered a very good absorber and a good material for shielding gamma – rays.

It can also be concluded that attenuation coefficient depends on the densities of woods. Figure 1 show that 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. The results in table 5 show that Ayin has the highest density amongst other woods collected.

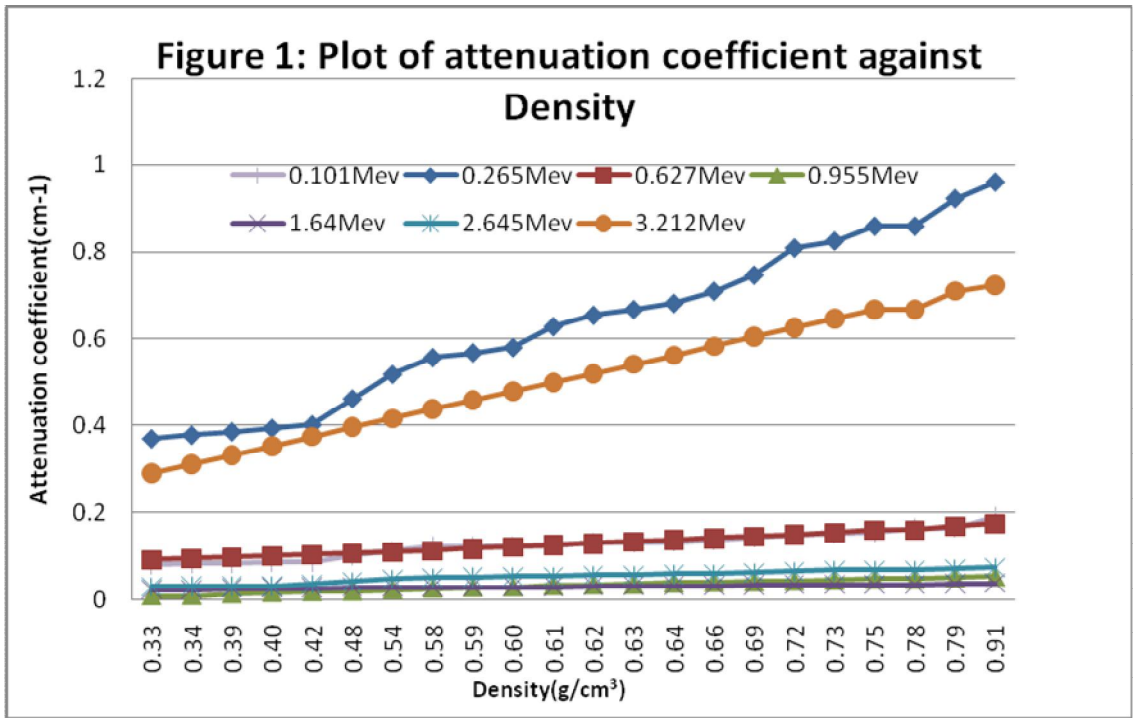
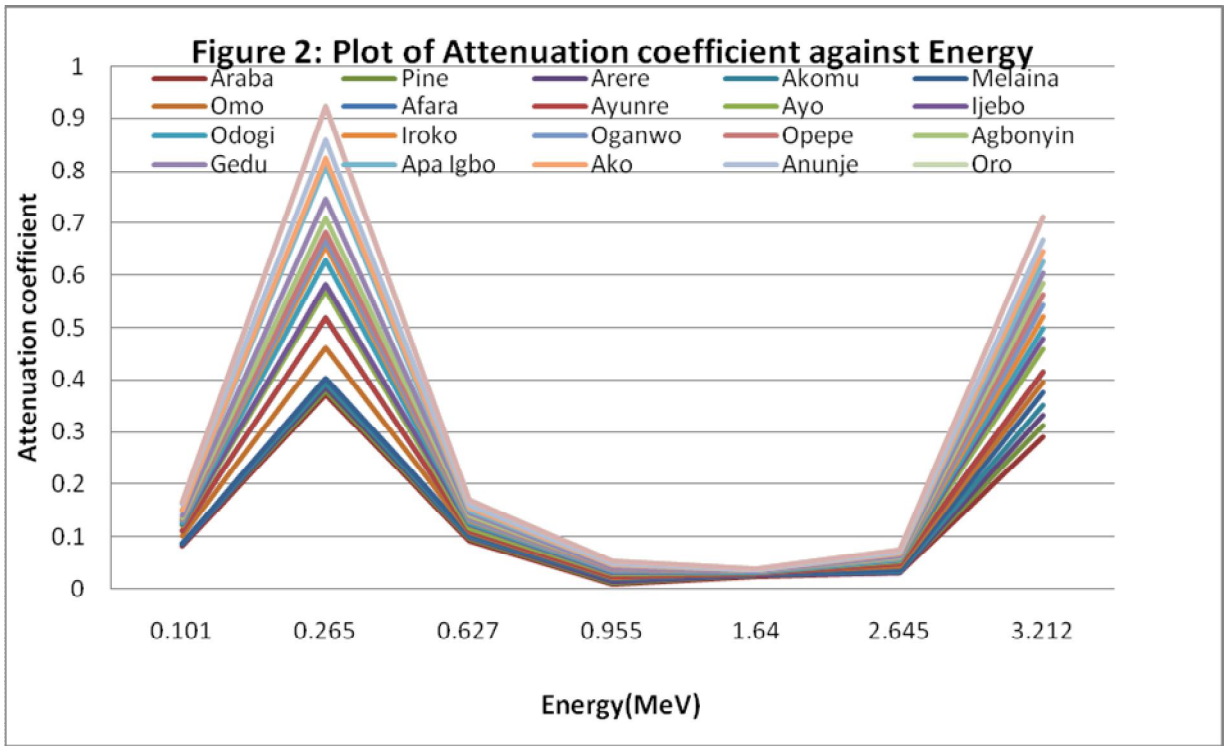


Table 6 displays the calculated half value layer for different woods used for the experiment. It can be seen that Ayin has the lowest half value layer while Araba os having the highest. It means that at the same energy of incident radiation, a lesser thickness of Ayin will be required to attenuation gamma radiation; a lesser thickness of Ayin will be required to attenuation gamma radiation to half its original intensity, when compared with other woods used in this experiment.



In summary, a wood of high attenuation coefficient would have low half value layer, this implies a good absorber of radiation. While, a wood of low attenuation coefficient would have high half value layer, this shows that the wood is a bad absorber of radiation.

From the foregoing, attenuation coefficient, density and half value layers are characteristics that can best be used in sorting the gamma radiation shielding abilities of materials. Looking at the result of this work, 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: Ayin, Oro, Anunje, Ako, Asunrun, Apa-Igbo, Gedu, Agbonyin, Opepe, Oganwo, Iroko, Odogu, Ijebo, Ayo, Ayunre, Afara, Omo, Melaina, Akomu, Arere, Pine and Araba.

CONCLUSION

The study of the shielding characteristics of woods is a necessary research that should continue. Since, the quest to protect our environment is increasingly becoming more important in our daily lives, it is therefore recommended that more research on shielding ability of material be carried out, and using more undiscovered tropical woods. The results of this will lead to the overall best attenuation for gamma radiations.

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