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Investigation of shielding of standard materials and glass for stopping 662 KeV gamma ray penetrations

Berun N. Ghafoor , Yadgar H. Shawn

Department of Physics, College of Education, Sulaimani University, Sulaimani, Iraq

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Corresponding Author:

Name: **Berun N. Ghafoor**

E-mail: **berun.ghafoor@univsul.edu.iq**

Yadgar.shwan@univsul.edu.iq

Tel:

ABSTRACT

Calculations on shielding are required for building a gamma ray radiography exposure room to ensure that the workers are exposed to radiation. The linear attenuation coefficient (μ) is a measurement used to evaluate the radiation diffusion and absorption characteristics of a medium. Despite the fact that, as radiation moves through a medium, its absorption is influenced by the radiation wavelength as well as the thickness and composition of the medium, the linear absorption coefficient is crucial in the interaction of radiation with matter. This study used a variety of materials as a shield for a gamma radiation source of 662 keV emitted by Cs-137. The results obtained through using a gamma source with a scintillation counter showed that the half-value thickness (HVT) for glass and aluminum were 3.57 cm and 3.39 cm, respectively, while for standard materials (concrete, iron, and lead) were 2.98 cm, 1.195 cm, and 0.58 cm, respectively.

1. Introduction

Gamma radiation is an electromagnetic radiation at the short-wave edge of the electromagnetic wave spectrum. By tradition, gamma radiation refers to the radiation originating in nuclei. Gamma radiation is emitted, absorbed, and transported as separate quanta. When gamma rays affect a sheet of absorbing material, some of the radiation will be absorbed or scattered. As the thickness of the material is increased, the fraction of the radiation passing through the material will decrease. A specific name is given to the thickness at which half the radiation is either absorbed or scattered and the other half passes through the material. This thickness is aptly called the half thickness $X_{\frac{1}{2}}$ [1].

Gamma rays passing through a thickness of $X_{\frac{1}{2}}$ would have half the intensity, i.e. counted as the original intensity. Material thickness is required for radiation to be attenuated by 50%, or reduced to half its initial intensity. An indicator of how readily electromagnetic radiation penetrates a substance is the attenuation coefficient. A common way to represent the attenuation coefficient is in terms of unit area per mass (cm^2/g). Estimating the transmission of gamma radiation through a selected thickness or thickness of shielding material necessary to achieve a specified degree of attenuation may be done using the attenuation coefficient and material density [2, 3].

Gamma attenuation coefficients are inversely proportional to gamma energy and directly related to the elements from which the shielding material is made. The findings of this study reveal that increasing the thickness of materials reduces the intensity of gamma rays. However, it is worth noting that the quantity of absorption varies depending on the material utilized (glass, aluminum, concrete, iron, and lead), with lead having the highest absorption rate. The results clearly illustrate that the linear absorption coefficient (μ) is affected by the incoming gamma ray quantity, atomic number, and absorber density [4, 5].

Liner attenuation coefficient and mass absorption are two characteristics commonly utilized in the study of gamma rays. These characteristics are primarily determined by elements, such as photon energy, absorbed nature, and the material through which radiation flows. The magnitude of the attenuation coefficient changes with material and density, and hence with photon energy, although particular values of the attenuation coefficient vary among materials for photons of a given energy [6].

To have a better understanding, the half thickness of each material was estimated. The half value thickness (HVT) of a material is the thickness at which the intensity of radiation entering the material is decreased by half [7]. This study aimed at measuring the half values of all layers as well as the linear and mass attenuation coefficients. In addition, it explained how materials could stop penetration of gamma ray at certain energy.

2. Materials and Method

Scintillation detector with 10% resolution, $700V\ H.V$ and $662\ keV$ energy was utilized. This detector detected gamma rays almost entirely. The Decade sealer Counter was used during the experiment to count the radiation released after traveling through the absorbers. Other materials utilized included a stand with a clamp for supporting the scintillation detector. The thickness of the absorbers was measured with a micrometer screw gauge. Glass, aluminum, concrete, iron, and lead absorbers were previously made and taken from the laboratory. The slope of the graph was calculated after exposing several absorber materials for gamma radiation of Cs^{137} and measuring the linear absorption coefficient. Materials of varied thicknesses, i.e. absorbers, were each put between the Radioactive Source Cs^{137} during the experiment. To monitor the radiation flowing through the absorbers, a detector (scintillation counter) was positioned immediately after the absorbers. The detector was connected to the cassy-lab to be amplified and a spectrum for the data gathered counts was created. Finally, the detector and cassy-lab were linked to a personal computer for data analysis and the creation of a spectrum to demonstrate how the spectrum varied (refer to figure 1).

Fig. 1: Schematic design of the experimental arrangement

3. Results and Discussion

In this study, the thickness of various materials (glass, aluminum, concrete, iron, and lead) was in the range of $(0-7.5)cm$. An experimental result for Cs^{137} gamma source was executed. Table (1) depicts the experimental outcomes of aluminum, glass, concrete, iron, and lead. The measuring time of $200\ sec$ was used in this study. This is due to that measuring time of photo peak is extremely sharp, giving a chance for the lowest count considered in this study in order for the rate of error to decrease to the minimum value.

Table 1: Measured count for different materials with different thickness (aluminum, glass, concrete, iron, and lead) using Cs-137 gamma sources

Thickness	Average counts per 200 sec				
|cm|	Aluminum	Glass	Concrete	Iron	Lead
0.0	7736	7736	7736	7736	7736
0.5	7046	7053	7122	5708	4285
1.0	6277	6239	6429	4324	2614
1.5	5591	5828	5590	3225	1256
2.0	5090	5364	4965	2350	728
2.5	4545	5002	4451	1697	474
3.0	4123	4413	3984	1396	207
3.5	3755	3989	3361	993	67
4.0	3383	3416	2921	728	0
4.5	3228	3033	2461	590	0
5.0	2957	2871	2119	398	0
5.5	2547	2493	1835	200	0
6.0	2119	2321	1504	180	0
6.5	1973	2146	1152	0	0
7.0	1649	1818	779	0	0
7.5	1591	1585	406	0	0

The measured count for several materials of varying thickness utilizing Cs-137 gamma sources is shown in table (1). The activity of the source will diminish as the thickness of each layer is increased until the materials have entirely absorbed the energy of gamma radiation.

The above data is used to draw the diagram of the intensity of counts and thickness of materials, as illustrated in Figure (2). Aluminum, glass, and concrete have roughly identical attenuation capabilities for Cs^{137} gamma sources, while iron and lead have higher attenuation capabilities.

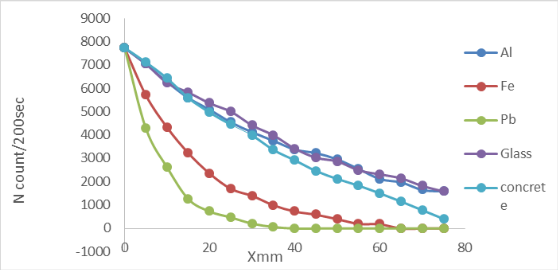

Fig. 2: Relationship between thickness and no. of counts

Table (2) shows the half value layers (HVLs) for each line. It is clear that each material has a specific capability to reduce the source's activity.

Table 2: HVLs for aluminum, glass, concrete, iron, and lead

Materials	HVLs |cm|
Lead	0.58
Iron	1.195
Concrete	2.98
Aluminum	3.39
Glass	3.57

The linear attenuation coefficients of the samples were estimated using the equation (1). In addition, they were calculated using the aforementioned technique (firstly calculating HVL from experimental data, and then computing attenuation coefficient; secondly calculating attenuation coefficient from slope, and then analyzing HVL). Based on results shown in Table (3), lead had the highest value, while glass had the lowest one.

The mass absorption coefficient was calculated by dividing linear attenuation to the material density [8-11]. Table (3) shows the mass attenuation coefficients for all samples that were close to each other except lead, which had the greatest value.

$$\mu = \frac{ln2}{HVL} \dots (1)$$

Table 3: Linear and mass gamma attenuation of aluminum, glass, concrete, iron, and lead

Materials	Density gm/cm^3	Linear attenuation Coefficients $\|cm^{-1}\|$	mass attenuation coefficients $\|cm^2/gm\|$
Lead	11.4	1.1948	0.1048
Iron	7.874	0.5799	0.07434
Concrete	2.895	0.2325	0.08018
Aluminum	2.7	0.2044	0.07570
Glass	2.7	0.1941	0.07188

Another way was employed to report the efforts made in this work by charting figure (3) to show the relationship between $\boldsymbol{Ln(No/N)}$ and the thickness of materials used in this work, and then taking the slope.

The direct value of that slope was converted into the attenuation coefficient value [11, 12], as listed in Table (4).

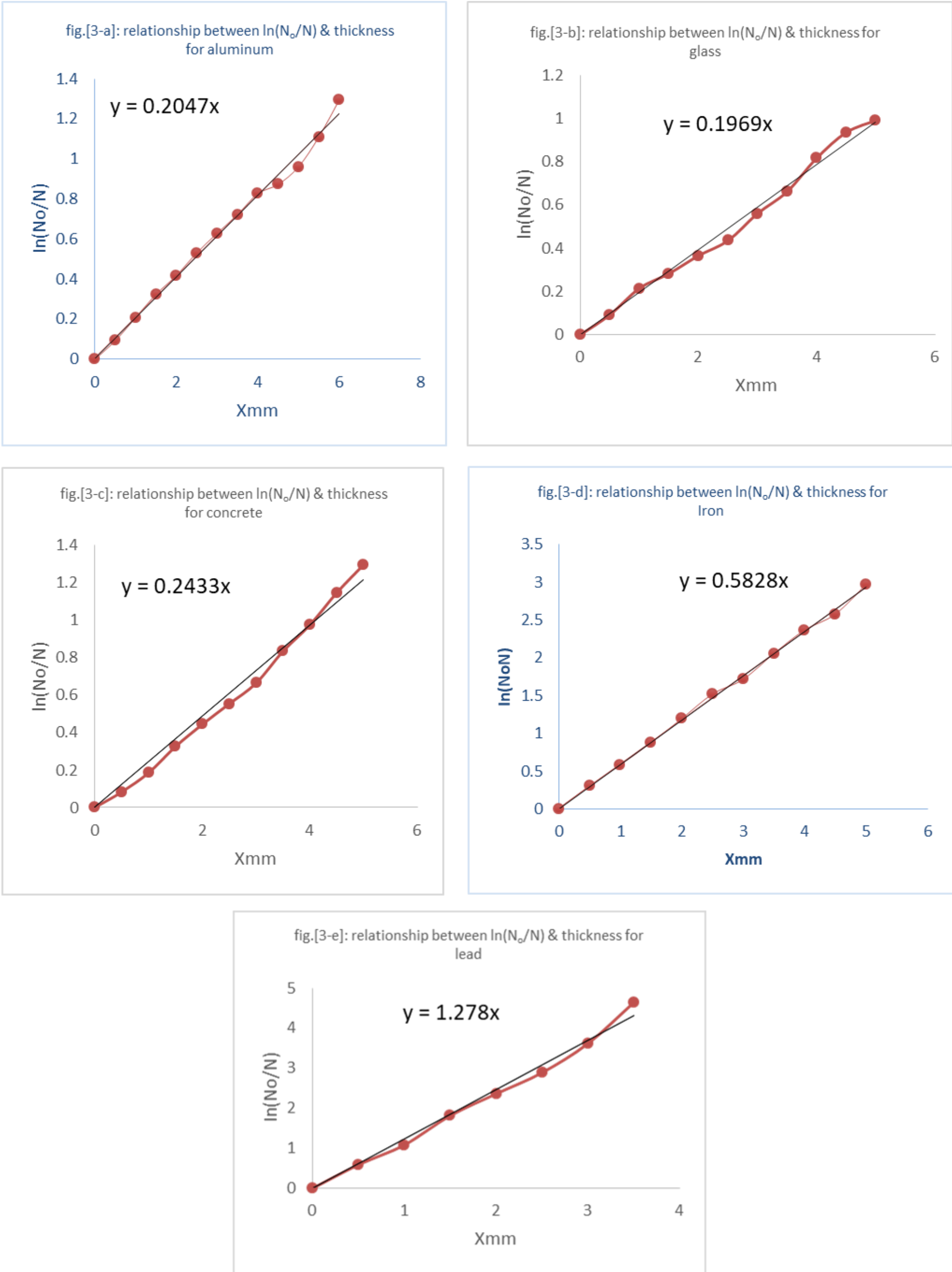

Fig. 3: The relationship between $ln(No/N)$ and thickness for materials

The attenuation coefficient for samples was calculated and HVLs were computed, as represented in Table (4). All samples' HVLs and linear attenuation coefficients were fairly similar for both techniques.

Table 4: The linear attenuation coefficients and HVLs from slope

Materials	Linear attenuation Coefficients $\|cm^{-1}\|$	HVLs $\|cm\|$
Lead	1.278	0.5422
Iron	0.5828	1.1891
Concrete	0.2433	2.8483
Aluminum	0.2047	3.3855
Glass	0.1969	3.5196

4. Conclusion

The HVLs, linear, and mass attenuation of aluminum, glass, concrete, iron, and lead materials were evaluated for Cs-137 gamma radiation. Lead had the greatest linear attenuation coefficient among all of other materials studied. Aluminum, glass and concrete had approximately equivalent linear attenuation coefficients, whereas iron is in the middle range among other materials. According to the findings, the attenuation coefficients were 0.194 cm^{-1}, 0.204 cm^{-1}, 0.232 cm^{-1}, 0.579 cm^{-1} and 1.194 cm^{-1}, for glass, aluminum, concrete, iron and lead, respectively. The shielding properties of glass, aluminum and concrete were compared to those of standard shielding (lead and iron) that may be employed as radiation shielding. On the other hand, lead was recognized to offer superior physical attributes, such as hardness and strength than iron, aluminum, concrete, and glass. As a result, lead-based materials had great capability as shielding materials for gamma radiation. According to the results of this work, the other materials under study could be used as shielding materials but with less capability.

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دراسة تدريع المواد القياسية والزجاج لايقاف اختراق اشعة جاما ذات الطاقة 662 كيليو الكترون فولت

بيرون نصرالدين غفور ، يادكار حسين شوان

قسم الفيزياء، كلية التربية ، جامعة السليمانية ، السليمانية ، العراق

الملخص

حسابات التدريع مطلوبة لبناء غرفة التعرض لأشعة جاما لضمان تعرض العمال للإشعاع. القياس المستخدم لتقييم خصائص انتشار وامتصاص الإشعاع للوسط هو معامل التوهين الخطي (μ). على الرغم من حقيقة أنه عندما ينتقل الإشعاع عبر وسيط ، فإن امتصاصه يتأثر بطول موجة الإشعاع وكذلك بسمك الوسط وتكوينه ، فإن معامل الامتصاص الخطي أمر بالغ الأهمية في تفاعل الإشعاع مع المادة. يستخدم هذا البحث مجموعة متنوعة من المواد كدرع لمصدر إشعاع جاما من 662 كيليو الكترون فولت المنبعث من Cs-137. أظهرت النتائج التي تم الحصول عليها باستخدام مصدر جاما مع عداد وميض أن سمك نصف القيمة (HVT) للزجاج والألمنيوم كان 3.57 سم ، و 3.39 سم بينما بالنسبة للمواد القياسية (الخرسانة والحديد والرصاص) كانت 2.98 سم ، 1.195 سم ، و 0.58 سم على التوالي.