

Linear attenuation coefficient calculation for both pure silicon (Si) and silicone supported with lead

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ABSTRACT

Linear attenuation coefficient was measured experimentally and calculated for both pure silicone, and silicone supported with lead. Two sizes of lead particles have been used 300 μm and 600 μm . The attenuation coefficients have been measured experimentally using slices of thickness (0-5) cm. Moreover, gamma radiation source have been used ^{137}Cs ($E_{\gamma} = 0.66 \text{ Mev}$) together with scintillation detector NaI (TI). The results showed that the attenuation coefficient of silicone with lead additive is greater than the attenuation coefficient of silicone alone. Besid that, it is found that the attenuation coefficient of silicone with lead additive of size 300 μm larger than that with lead additive of large than size 600 μm .

Key words: attenuation coefficient, gamma source, NaI detector.

1-INTRODUCTION

Radiation shielding is essential for the protection of human and environment because the harmful effects of ionizing radiations can cause significant health hazards with the development of technology, human health has started to be exposed to extra radiation and this can damage the human cell [1]. There is always a need to develop material, which can be used under harsh conditions of nuclear rays exposure and can act as shielding material [2].

The goal of this research is to find new alternatives of nuclear shields easy to make and modulation made from silicon composite supported with different materials have a good ability to radiation attenuation and absorption of gamma-rays with a large and wide extent of application in the industrial, medical fields.

Masayuki Igashira, Hideo Kitazawa, and Nobuhiro Yamamuro in 1986 [3] suggested (20-80 wt %) mixture of paraffin and boric acid as a shielding material for the gamma ray detector used in fast neutron experiments. Its neutron shielding capability was evaluated by neutron and gamma-ray transport calculations and compared with that of other materials. As a result, it was found that the borated paraffin will be an effective and economical shielding material against fast neutrons if it is used with a lead shield.

A.A.Al-Bayati in 2003 [10] measured the absorption coefficient of gamma-ray in some shielding materials, such as, iron, brass, lead and concrete using a ^{137}Cs gamma source of energy 0.662 MeV two types of concrete samples are used, ordinary concrete and concrete with additive fractional weights of iron or brass or lead materials Experimental measurements are carried out for single-layer absorbers. The results showed that for concrete, the value of gamma-ray absorption coefficient can be increased if a material of high atomic number (or density) is added to it.

In 2010 Hefne Jameel [4] estimate in this study a comparison of gamma ray linear attenuation coefficient of two types of shielding materials made of Saudi white and red sand. Each shield was consisted of one part of cement two parts of sand in addition to water. Different thicknesses were tested. The average linear attenuation coefficients were found to be (0.17 cm^{-1} and 0.15 cm^{-1}) for white and red sand shields respectively. The study shows that white sand is better for attenuating gamma ray compared to the red sand.

2-Theoretical concept

The attenuation of γ -rays beam in an absorber, is sketched in figure (1) follows a true exponential variation with the distance of penetration which is unlike that of charged particles as shown in equation (1)[8].

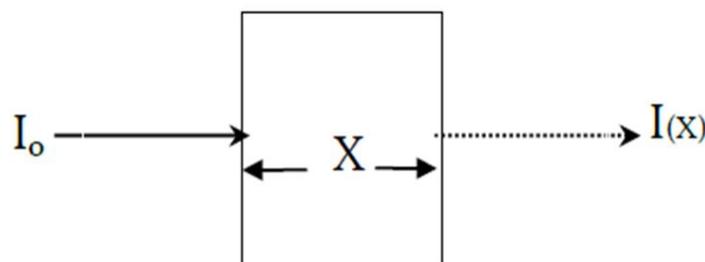


Fig (1) Attenuation of γ -ray beam through an absorber of thickness (X)

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

This expression tells us that the radiation will decrease in an exponential fashion with the thickness of the absorber x with the rate of decrease being controlled by the linear attenuation coefficient μ . Attenuation means either scattering or absorption. Since either process will remove the Photons from the beam. The Attenuation coefficient is therefore the probability per unit path of interaction; it is what we would call the macroscopic cross-section $\Sigma = N\sigma$ in the case of neutron interaction, where N is the number of atoms per unit volume and σ is the microscopic cross-section [9].

The attenuation of gamma can be described by the following equations:

$$I = I_0 e^{-\mu d} \quad (2)$$

$$\ln(I_0/I) = \mu d \quad (3)$$

Where:

I = intensity after shielding

I_0 = incident intensity

μ = attenuation coefficient (cm^{-1})

d = thickness of absorber (cm)

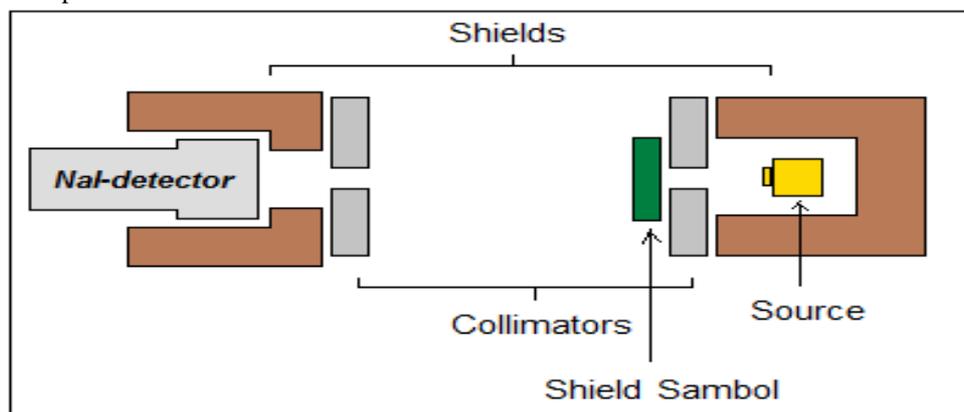
The attenuation coefficient is dependent on the energy of the incident gamma radiation and the elemental composition of the shielding material. Attenuation coefficient can be determined by measuring I and I_0 for a shielding material of known thickness (d). Comparing the thicknesses of different materials needed to achieve the shielding requirements for a particular application, along with other factors, such as the cost, weight, chemical, and physical durability of the materials, will then allow one to choose the most appropriate type of shielding [5].

3. Experimental Details:-

In present study, measurement system consist NaI (TI) scintillation detector consists of a thallium-doped sodium iodide crystal which is permanently coupled to a photomultiplier. The detector is sealed assembly which includes a 2.5"×2.5" NaI (TI) crystal and a photomultiplier tube, which contains a high-voltage divider network to supply all necessary voltage for dynodes [6]. And radioactive source Cesium-137 has a half-life of 30 y that emits photons of gamma ray with average energy value of 0.662 MeV [7]. Two collimators are used where each one is a lead block of 5 cm radius and 1.5 cm width, with a central hole of 1.7 cm radius. as show in the figure (2).

Silicone material in the form of gel (U.S.A production) have been used which negotiable hardening by adding reinforcement material like (Pb) for the purpose of producing shields is intended to be used in shielding against gamma-ray.

Number of shields that were used in this research is twenty shields specific size powders. All samples shield are made in the form circular discs 4cm in diameter. Thickness of each disc 1cm., five made of pure (Si) shields, five made from Si with lead additive of size 300 μm shields, five made from Si with lead additive of size large than 600 μm . and the last five made from pure Pb.



Experimental arrangement used in the present work

Fig 2)(

4. Results and Discussion

To determine the effects of lead additive to polymer, its attenuation coefficient is examined, and then its coefficient increases in case of composite as compared with polymer alone. The attenuation coefficients have been experimentally measured first for polymer alone pure (Si), different thicknesses of these polymer have been used separately to determine the attenuation coefficient of this material using ^{137}Cs . gamma source, and for pure (Pb). The results of these experimental measurements have been tabulated in table (1), (2), this tables has been used to plot graphs to determine the attenuation coefficient for this materials. Graph of $\ln(I/I_0)$ as a function of absorber materials thickness in (cm) have been plotted for this material to determine the attenuation coefficient using ^{137}Cs gamma source ($E_\gamma = 0.662$ MeV) as shown in figure (3),(4). Experimental results for linear attenuation coefficient μ is (0.07 cm^{-1}) for pure (Si)

and (1.23 cm^{-1}) for pure (Pb). The value of linear attenuation coefficient μ for pure (Pb) is fully compatible with the practical results of previous studies [11].

Table (1) the experimental liner attenuation coefficient measurement for pure Si using ^{137}Cs gamma source ($E_\gamma = 0.662$ MeV)

X_{cm}	I_{av}	I_{av}/I_0	$\ln I_{\text{av}}/I_0$
0	267749	1	0
1	248149	0.92	-0.07
2	229059	0.85	-0.15
3	211869	0.79	-0.23
4	196367	0.73	-0.31
5	180917	0.67	-0.39

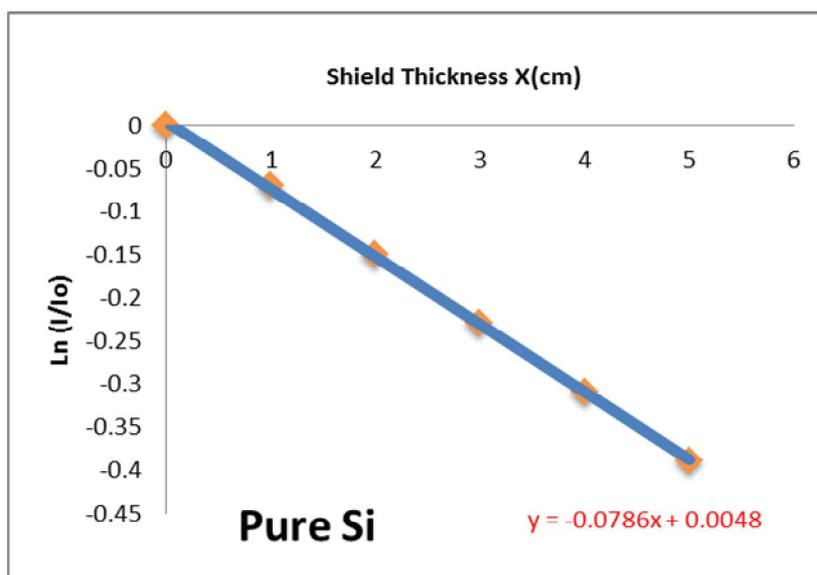


Fig (3) $\ln(I/I_0)$ as a function of of absorber thickness for (pure si) for (^{137}Cs gamma source ($E_\gamma = 0.662$ MeV)

Table (2) the experimental liner attenuation coefficient measurement for pure Pb using ^{137}Cs gamma source ($E_\gamma = 0.662$ MeV)

X_{cm}	I_{av}	I_{av}/I_0	$\ln I_{\text{av}}/I_0$
0	2267749	1	0
0.2	224314	0.83	-0.17
0.5	154477	0.57	-0.55
1	78965	0.29	-1.22
1.5	43625	0.16	-1.81

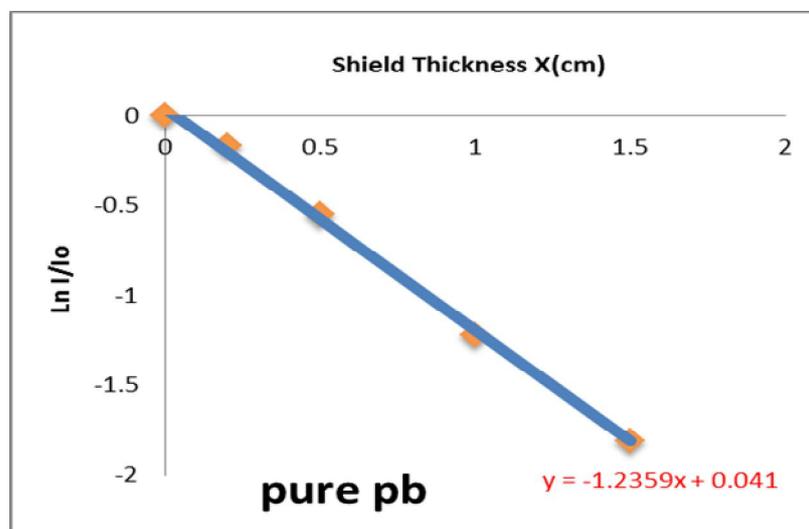


Fig (4) $\ln(I/I_0)$ as a function of of absorber thickness for (pure Pb) for (^{137}Cs gamma source ($E_\gamma = 0.662$ MeV)

The attenuation coefficients have been experimentally measured for composite material (Si with Pb) with two type of particles size (300 μm), more than (600 μm) for different thicknesses. The results of these experimental measurements have been tabulated in tables (3,4) This tables have been used to plot graph to determine the attenuation coefficient for this materials. Graph of $\ln(I/I_0)$ as a function of absorber material thickness in (cm) have been plotted for this material to determine the attenuation coefficient using ^{137}Cs gamma source ($E_\gamma=0.662\text{MeV}$) as shown in figures (4),(5). The experimental result show the attenuation coefficient μ for first shield (300 μm) is (0.33 cm^{-1}), and (0.31 cm^{-1}) for second shield more than (600 μm). Experimental results in fig (5,6) show the attenuation coefficient of first type shield greater than the attenuation coefficient of the second type shield that means first type shield is the best in gamma radiation attenuation from the second type.

Table (3) the experimental linear attenuation measurement for Composite (lead with si) using particals size (300 μm) using ^{137}Cs gamma source ($E_\gamma = 0.662 \text{ MeV}$)

X_{cm}	I_{av}	I_{av}/I_0	$\ln I_{\text{av}}/I_0$
0	267749	1	0
1	194385	0.72	-0.32
2	138158	0.51	-0.66
3	99870	0.37	-0.98
4	72024	0.26	-1.31
5	52211	0.19	-1.63

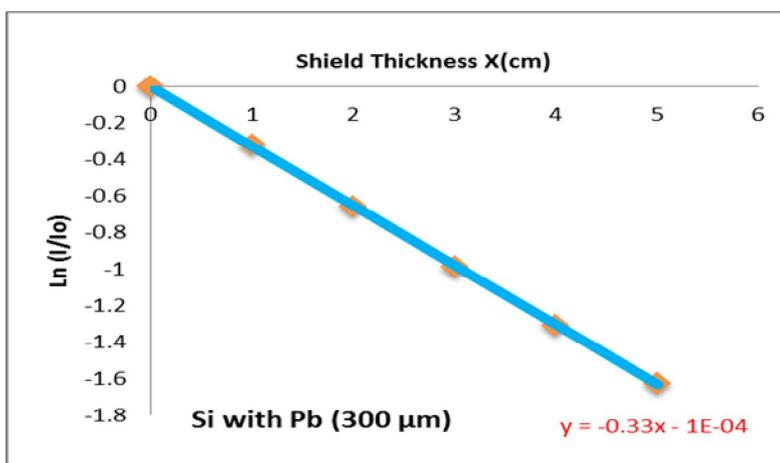


Fig (5) $\ln(I/I_0)$ as a function of composite (si with pb) absorber thickness using lead particals size (300 μm) for ^{137}Cs gamma source ($E_\gamma = 0.662 \text{ MeV}$)

Table (4) the experimental linear attenuation coefficient measurement for composite (lead with si) using particals size (more than 600 μm) using ^{137}Cs gamma source ($E_\gamma = 0.662 \text{ MeV}$).

X_{cm}	I_{av}	I_{av}/I_0	$\ln I_{\text{av}}/I_0$
0	267749	1	0
1	198353	0.74	-0.30
2	144034	0.53	-0.62
3	105641	0.39	-0.93
4	76711	0.28	-1.25
5	56263	0.21	-1.56

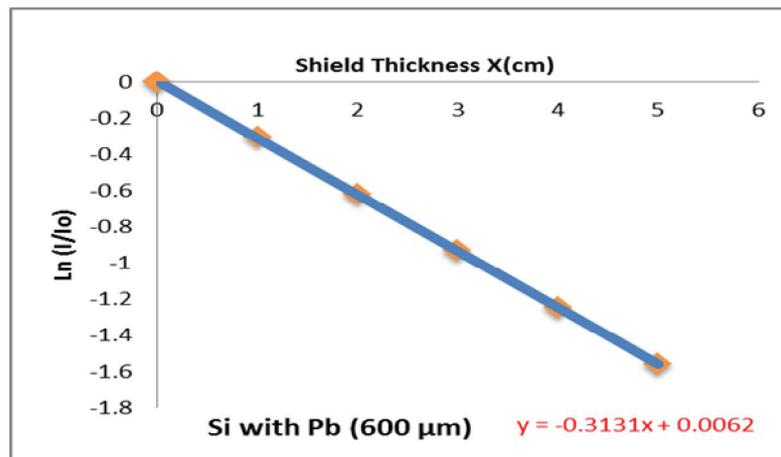


Fig (6) $\ln(I/I_0)$ as function of composite (Si with pb) absorber thickness using lead particals size (600 μm) for ^{137}Cs gamma source ($E_\gamma = 0.662 \text{ MeV}$)

5- Conclusions

Three types of shield were prepared and the attenuation coefficient of each type were measured. From the results we can conclude that the attenuation of shield consist from (Si with lead) is best from the shield of pure (Si). On the other hand, the attenuation of shield that is prepared from silicon with particle size (300 μm) of lead is greater than the attenuation of shield was prepared from silicone with particle size (more than 600 μm) of lead because In the case of the big particle size absorber (more than 600 μm) the blanks between particles are large and hence the chances of interactions are reduced. In other words, the radiation has a greater probability of being transmitted through the absorber and the attenuation is consequently lower than in the small particle size case.

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