IRJSE *Int. Res. J. of Science & Engineering*, 2018; Special Issue A2 : 128-131
ISSN: 2322-0015
SJIF Impact Factor 4.11
UGC Approved Journal No. 63628
RESEARCH ARTICLE
OPEN ACCESS

Study of linear absorption and mass attenuation coefficient of various materials using G. M. Counter

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Manuscript Details
Available online on http://www.irjse.in
ISSN: 2322-0015

Editor: Dr. Arvind Chavhan

Cite this article as:
Kadhum Saad Jundee, Yande Jyoti and Aghav SD. Study of linear absorption and mass attenuation coefficient of various materials using G. M Counter, *Int. Res. Journal of Science & Engineering*, January 2018; Special Issue A2: 128-131

ABSTRACT

In the areas where the people have to encounter ionizing radiation daily, it is necessary to provide shielding materials for radiation safety. Present study is intended to investigate the attenuation coefficient for the various materials of different thickness as absorbers for radioactive source and establish the relations among linear attenuation coefficient, mass attenuation coefficient and density of materials. Radioactive sources Co^{60} was used as sources of the gamma rays. Geiger Muller counter is used as detector. Lead, aluminum, iron, stainless steel, glass, plastic and wood materials are used as absorber.

It had been observed that attenuation can be achieved using a wide range of materials. Once basic principles involved in gamma ray interaction with matter is understood, it will be easier to select shielding material for given application. Though lead had found to have a higher attenuation coefficient and have a better radiation shielding rather than others but it is not environment free. Linear attenuation coefficient, mass attenuation coefficients, half value layer HVL($X_{1/2}$) of absorber materials is calculated and study will be useful in selecting shielding material.

Key words: G. M. Counter, mass absorption coefficient, nuclear safety, cobalt Co60, shielding material.

INTRODUCTION

The provision of enough protection against nuclear radiation remains an important problem in the countries which are exposed to nuclear radiation. Radiation protection is serious concern in nuclear power plants, industrial or medical x ray system, particle accelerator and radiology. In such areas people are exposed to ionizing radiation continuously. The provision of adequate protection from undue exposure of radiation to individual is necessary as harmful effects of ionizing radiation can cause significant health hazards [1]. Radiation shielding depends on principle of attenuation, stopping power of radiation particles and the shielding material used [2]. Most common structure of defending materials include rigid materials such as high density concrete, lead bricks, steel plates and cooling pools filled with water. They have insufficient portability. The gamma attenuation of these materials has been usually studied [3].

In addition to these well distinguished shielding materials, complex materials are becoming increasingly available. Even lead free composite material from tungsten can be used against electron beam in radiotherapy [4].The attenuation of gamma radiation is dependent upon the energy of the incident gamma radiation, the atomic number, density of the elements in the shielding material, and the thickness of the shielding. Composite materials may offer additional benefits in chemical resistance, physical durability and portability [5, 6]. Present study deals with comparative study of linear attenuation coefficient, mass attenuation coefficients, half value layer of six materials.

METHODOLOGY

Equipment/Accessories used consist of G.M Counting System with detector. Radioactive sources Co-60 is used as gamma ray source. Aluminum ,Iron ,Steel ,Glass, Plastic and wood absorber set with 1 mm thickness each one also lead absorber two slab 0.5 cm each one.

Procedure adopted is as follows.

Set GM voltage at the operating voltage of the GM tube (Fig1a). Without source, make a few (about 5 readings) background measurements and take an average for a preset time of say 60 sec. Compute Average background counts in 60 sec ($Ba = (b_1+b_2+b_3+b_4+b_5) / 5$).Compute Background rate = Ba/t (t = 60sec). Place a Gamma source in the source tray at about 7 cm from the end window of the GM tube and take reading of zero absorber thickness. Take the Aluminum absorber set. Place an aluminum absorber of 1mm thickness in the absorber holder at about 2 cm from the end window of the GM tube and record the counts for three times and take mean. The absorber thickness is increased in steps of 1mm up to 1cm and every time counts are recorded [7].

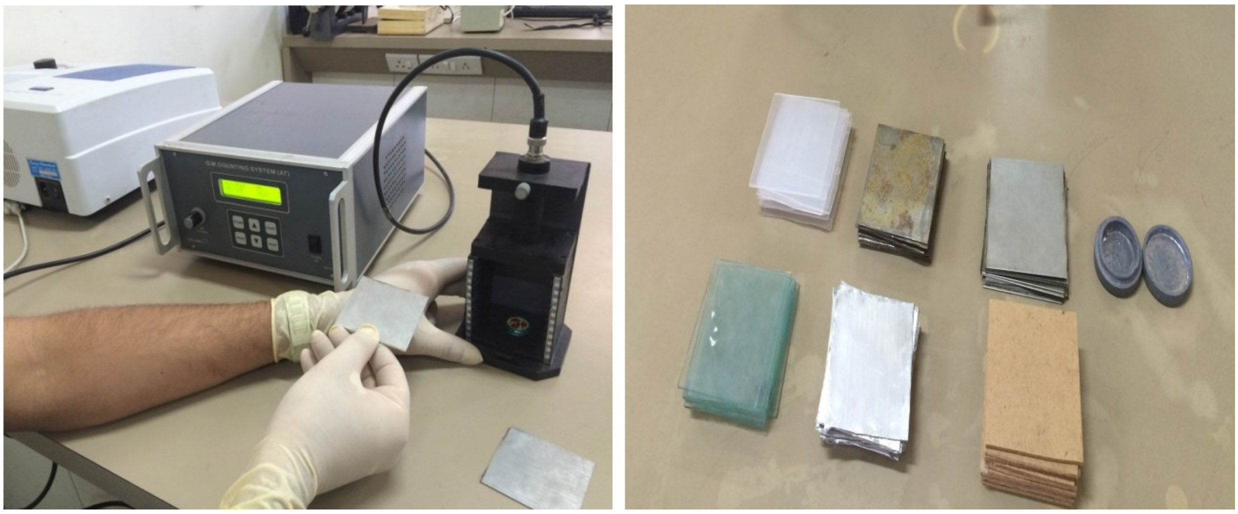

Fig 1 (a) G M Counter **(b) Absorbers**

This process is repeated with all absorbers that used in this study (Fig1b). Data is to be collected for Co-60 source. (35 KBq, Mar-2015);Half-life for Co-60 is $T_{1/2}$=5.2714 y) having present activity (A) =31.367 KBq.

Subtract the background count rate from each measured count rate. Plot a graph of corrected counts(I) VS absorber thickness (Fig.2). Find I_0 for x=0 by extrapolation of the curve for I/I0=0.5 and obtain X1/2.From the plotted graph extrapolate and obtain X1/2. Half value layer (HVL) of absorbing medium is defined as thickness X1/2 which will cut the initial intensity to half. Substitute X1/2 in the equation μ= 0.693/x1/2 to calculate linear absorption coefficient. Once linear absorber /attenuation coefficient is known, we can find out mass attenuation coefficient μm = μ/ρ where ρ is density of material of the absorber.

RESULTS AND DISCUSSION

Table 1 indicates comparison of half value layer, linear absorption and mass absorption coefficients.

Measuring count rate as a function of Gamma energy:1-Isotope: Co 60

Distance between source and detector: 5(cm), Time: 60 (sec), Operation voltage: 450 volt count with source without Absorber=1756

Background count (NB) = 15.3 Background count rate (IB) = 0.255, count rate=29.2.

These measurements are shown in Table 2.

Energy calculated by formula = (R+160)/543 MeV, Where R is taken from the Graph of Log Nc Vs mx , i.e. intersecting point of line with X axis. Count rate depends on density and thickness of material

Table 1: comparison of half value layer, linear absorption and mass absorption coefficients.

Material	Density(g/cm³)	X1/2(cm)	μL (cm⁻¹)	μm(cm²/gm)
Stainless steel	7.9	0.1	6.93	0.87
Iron	7.874	0.11	6.93	0.88
Al	2.7	0.12	5.775	2.13
Glass	2.58	0.11	6.3	2.44
Plastic	1.05	0.085	8.15	7.7
Wood	0.7	0.09	7.7	11

Table. 2: Measuring count rate as a function of Gamma energy:1-Isotope: Co 60

Material	Thickness (cm)	Absorber Mass thickness (gm/cm2) = thickness X-density	Count (1)	Count (2)	Count (3)	Mean	Count rate	Corrected Count rate (I)	Ln(I)	Emax MeV
Lead (Pb)	0.5	5.67	502	499	461	487.3	8.12	7.86	2.06	0.298895
	1	11.34	365	386	383	378	6.3	6.045	1.799	
S.steel	0.5	3.95	479	539	508	508.6	8.47	8.22	2.106	0.297422
	1	7.9	480	500	494	491.3	8.188	7.933	2.07	
Iron(Fe)	0.5	3.937	538	586	527	550	9.166	8.911	2.187	0.297238
	1	7.874	496	516	515	509	8.48	8.228	2.107	
Aluminum (Al)	0.5	1.32	609	584	554	582.3	9.705	9.45	2.14	0.299263
	1	2.64	552	508	531	530	8.83	8.57	2.149	
Glass	0.5	1.29	620	570	588	592.6	9.87	9.62	2.264	0.299171
	1	2.58	570	534	544	549.3	9.155	8.9	2.186	
Plastic (polystyrene)	0.5	0.525	570	610	605	595	9.916	9.661	2.26	0.292818
	1	1.05	572	603	631	568.6	9.476	9.221	2.221	
7-Wood (MDF)	0.5	0.35	617	584	568	568.6	9.826	9.5716	2.258	0.293278
	1	0.7	581	572	590	581	9.683	9.428	2.243	

CONCLUSION

The present study provides the values of the gamma-ray mass attenuation coefficients, linear absorption coefficient and half value layer of materials (stainless steels, Iron, aluminum, Plastic, glass, Plastic and wood). Our results show that attenuation can be achieved using a wide range of materials. Once basic principles involved in gamma ray interaction with matter is understood, it will be easier to select shielding material for given application. Interaction of gamma radiation with matter obeys the exponential attenuation law. There is decrease of the attenuation coefficient with increasing energy of gamma quanta and increase of the attenuation coefficient with increasing atomic number of the absorber.

Acknowledgement:
Authors are grateful to Principal Dr. M.G. Chaskar of Baburaoji Gholap College and office beares of P.D.E.A .Pune for allowing us to use the facility in labortory. Saad Jundee Kadhum acknowledge Republic of Iraq for felloship offered by government for his P.G.study.

Conflicts of interest: The authors stated that no conflicts of interest.

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