IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

COMPARATIVE STUDY OF SHIELDING PARAMETERS FOR CARBON AND LEAD USED IN NAI (TL) DETECTOR

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Abstract: The shielding parameters of two materials for carbon and lead were measured and calculated based on the attenuation coefficient values in the energy range of 511keV to 1332keV. These values are obtained by calculating the exponential absorption equation by using the radiation intensities before and after count rates. The radioactive sources were placed in front of the detector and the various thickness of the sample were placed between the source and the photo-multiplier tube (PMT) of the NaI (Tl) detector.

Key words **-** shielding parameters, attenuation coefficient, radiation intensities, and NaI (Tl) detector.

I. INTRODUCTION

The radiation shielding parameters are a necessary and consideration of any shielding calculation. Shielding is an important fundamental method by which exposure to external radiation may be reduced to acceptable levels. Shielding materials are protected from corrosion, chemical reaction, and radiation damage. In the field of industry research and medicine is widely used radioisotope as a compact source that is predictable nuclear radiation. Some radioisotopes are available in source strengths of the order of several thousand curies. In this work, the radioisotope of gamma sources Na-22, Co-60, and Cs-137 was used. The gamma radiation is incident in any finite of materials, there exists some probability that the radiation with interacting in the materials and the radiation after passing through the medium is attenuate. The term attenuation refers to the remaining photons that have either been absorbed or scattered in the layer of interaction medium. The following two are the gamma attenuation of narrow beam attenuation and broad beam attenuation. The narrow beam is called a good geometry condition. In many applications, the necessary shielding thickness and interaction parameters were calculated by the following exponential relation.

$$I = I_0 \exp(-\mu t).$$

The gamma ray collides with any absorber materials would be also considered, the three fundamental methods of the photoelectric effect, Compton scattering, and pair production. The attenuation of radiation due to the variety of metal thicknesses are summarized. The attenuation of gamma radiation may also be expressed in terms of parameters called Half Value Layer (HVL) thickness.

II. MATERIALS AND METHOD

The linear attenuation constant represents the combined cross-sectional of all interaction mechanisms for the photons.

$$\mu = t\ (\text{Photoelectric}) + s\ (\text{Compton}) + K\ (\text{Pair})$$

The linear attenuation constant depends on the amount of the material and each of the interaction processes removes the gamma-ray from the beam either by absorption or by scattering from the detector direction and may be characterized by a tough and quick probability of prevalence per unit path length among the absorbent. The number of transmitted photons is then given in terms of the number without an initial intensity is following.

$$\frac{I}{I_0} = e^{-\mu x}.$$

The ratio of the linear attenuation to the density (μ/ρ) is called the mass attenuation coefficient. The compound of a mass attenuation coefficient materials can be calculated by the following relation.

$$\left(\frac{\mu}{\rho}\right) = \sum_i w_i \left(\frac{\mu}{\rho}\right)_i.$$

The measure of HVL can be achieved by direct measurements and graphical analysis. The homogeneity of the beams can be verified by the radio of the first and second HVLs of the material. The effectiveness of gamma ray shielding is frequently described in terms of HVL and can be calculated by the following relation.

$$HVL = \frac{\ln 2}{\mu}.$$

The gamma-ray counting system should be calibrated and the working voltage of the NaI (Tl) detector was determined practically at 650V and the counting time is 300s. The slabs samples of various thicknesses were placed in the path of the beam of the gamma rays, from radioactive sources, and the detector was responding to the record on the MCA. When the gamma rays were passes through the solid matter, the intensity of gamma rays was decreasing. The gamma-ray intensity is attenuated after the process of Compton scattering, the photoelectric electric effect, or the pair production.

2.1 Sodium Iodide Detector

The NaI (Tl) detector can also be used for counting and energy discrimination. Iodine has a high atomic number in NaI crystal, it can be obtained high detection efficiency. Usually, a small amount of thallium is added to the crystal in order to activate and this new structure is called Nal (TI) detector, and it can be seen from the figure (1).

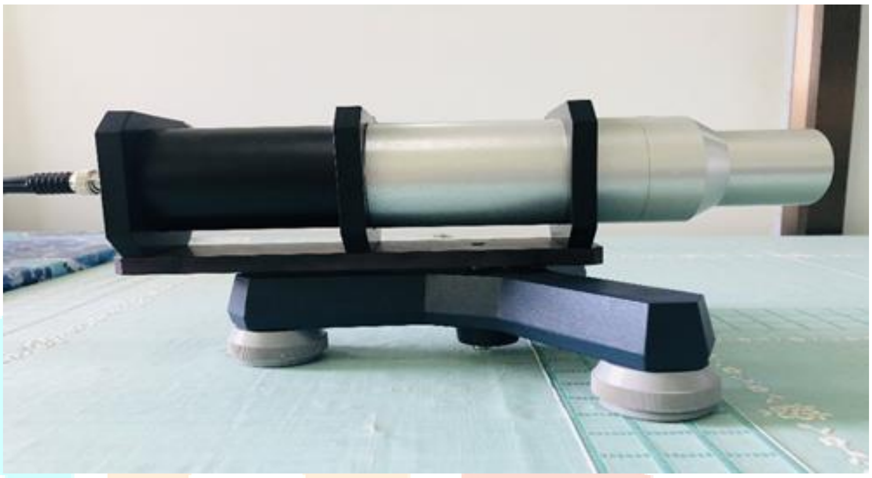

Fig. 1 Photography of NaI (Tl) detector

2.2 Gamma Spectrometer System and Absorber Materials

The gamma ray spectrometer was used to radioactive and measure the radioisotope source of radioactivity. It can also identify the energy of gamma rays of samples. The gamma spectrometer consists of a detector NaI (Tl), counting electronic system, high voltage, preamplifier, amplifier, and multichannel channel Analyses (MCA), and a PC, where software was installed to record data. The detector is shielded concrete using 6 cm on all sides to reduce the background level of the spectrometer system. Figure (2) shows the photography of the gamma spectrometer system. The radioisotope as sources and the attenuation of radiation due to the variety of absorber thicknesses are used carbon and lead in this work as shown in figure (3).

Fig 2. Laboratory equipment for the measurement of gamma radiation spectrum with the scintillation detector

Fig 3. The gamma-ray sources and absorber materials of carbon and lead

III. RESULT AND DISCUSSION

Before using a gamma spectrometer system, it should be calibrated the response of radiation to the detector by using a known radiation sources. In this work energy calibration of Na (Tl) detector has been done using Na-22, Cs-137, and Co-60 gamma ray sources. The different nuclear parameters of sources are given in table 1. Figures (4) and (5) are shown the energy calibration curve and the efficiency curve of the NaI (Tl) detector. The measure gamma-ray spectra of Co, Cs, and Na were shown in figure (6) and (7). The measure spectra clearly indicated two well-separated photo peaks with and without absorber corresponding to the gamma energies. The linear attenuation coefficients for four different energies have been obtained using a gamma spectrometer. The all calculated results are shown in tables 2 and 3.

The photon interaction parameters were measured by means of transmission equipment and the equation $I = I_0 \exp(-\mu t)$ was used in carrying out the shielding calculation. Attenuation coefficients of materials are evaluated then tabulated using equations 3.1 and 3.2. Where I_0 and I were the intensity of initial and after passing through the absorbers, t is the thickness of absorber materials, ρ is the density of absorber materials, μ and μ_m were the linear and mass absorption coefficients. Figure (8) to (11) are shown the radiation intensities are exponentially decayed after passing through the different thickness of absorber materials for the corresponding energies.

$$\mu = \frac{1}{t}\ln\frac{I_0}{I} \qquad (3.1)$$

$$\mu_m = \frac{\mu}{\rho_m} \qquad (3.2)$$

Table1. Nuclear parameters for standard gamma ray sources

Sr. no.	Gamma source	Gamma energy (keV)	Initial activity (Bq)	Half life (years)
1	60-Co	1173	37000	5.3
		1332		
2	22-Na	511	185000	2.6
3	137-Cs	662	185000	30.1

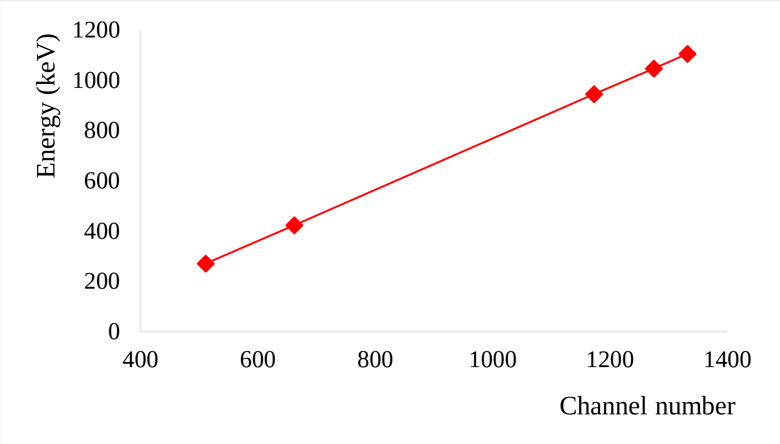

Fig 4. Energy calibration curve for five different energies of NaI (Tl) detector

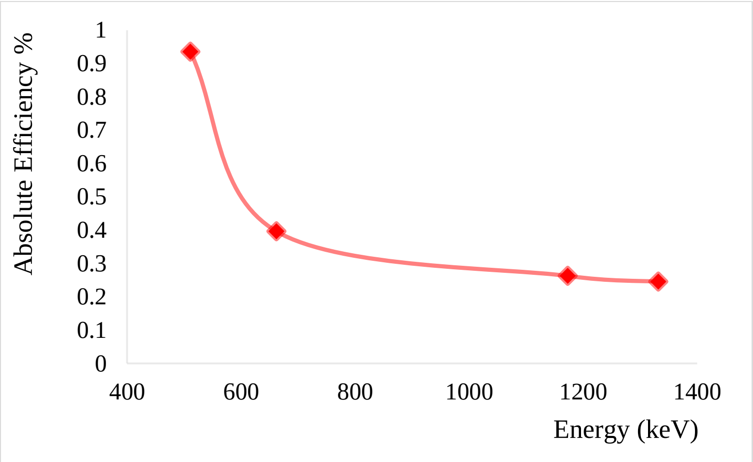

Fig 5. Efficiency curve of NaI (Tl) detector

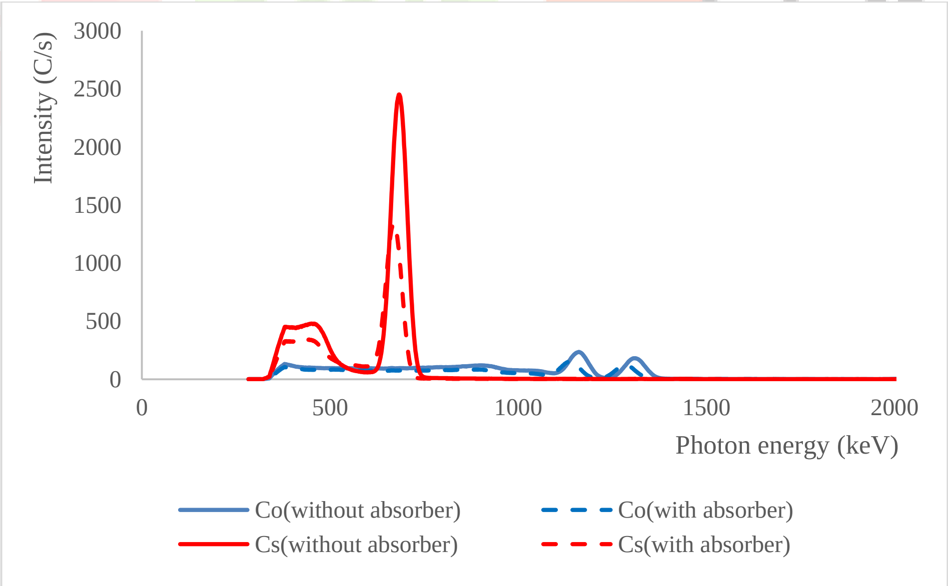

Fig 6. The measure gamma ray spectra with and without absorber of Co-60 and Cs-137

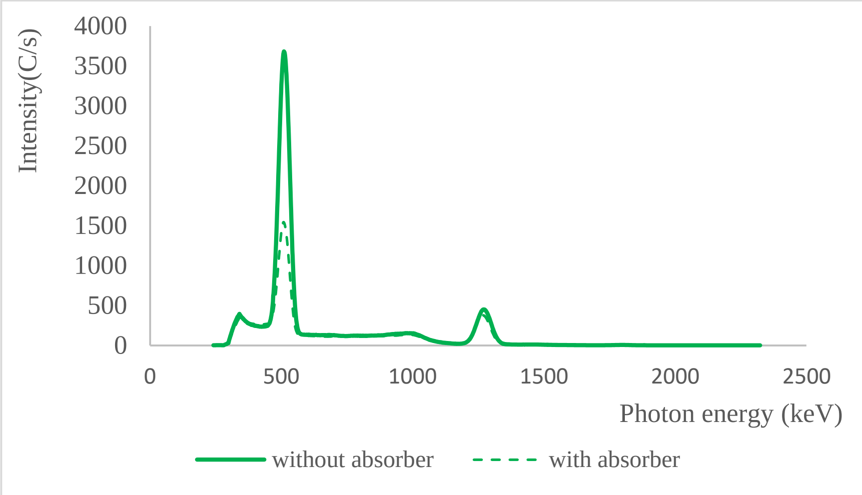

Fig 7. The measure gamma ray spectra for Na-22 with and without absorber

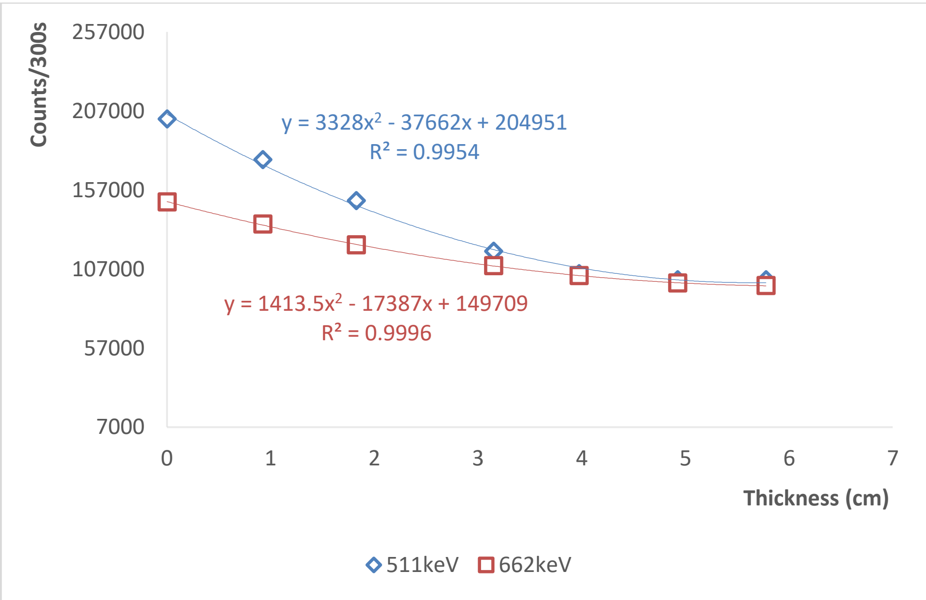

Fig 8. Count rate and absorber thickness of carbon for 511 and 662 keV

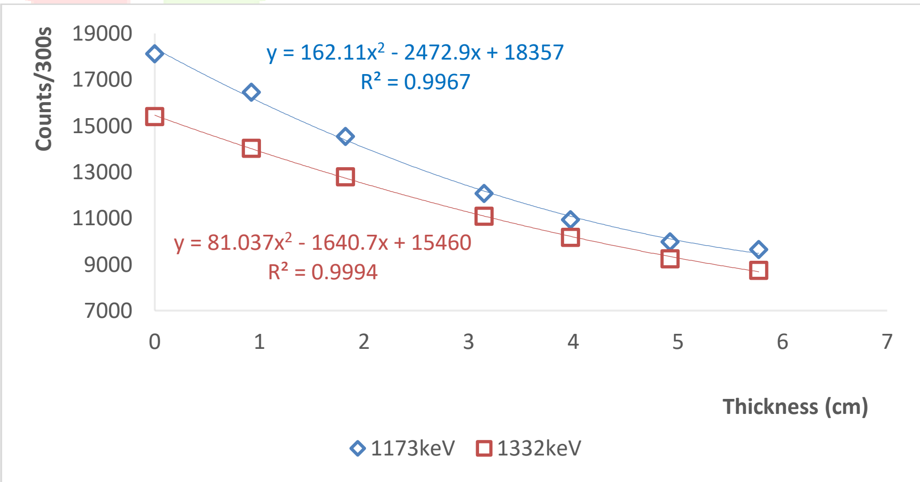

Fig 9. Count rate and absorber thickness of carbon for 1173 and 1332 keV

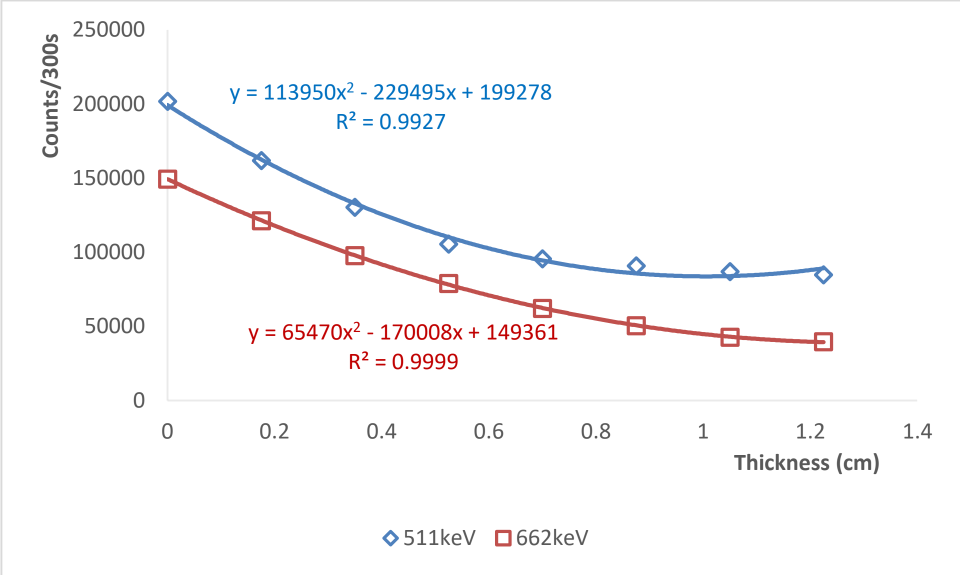

Fig 10. Count rate and absorber thickness of lead for 511 and 662 keV

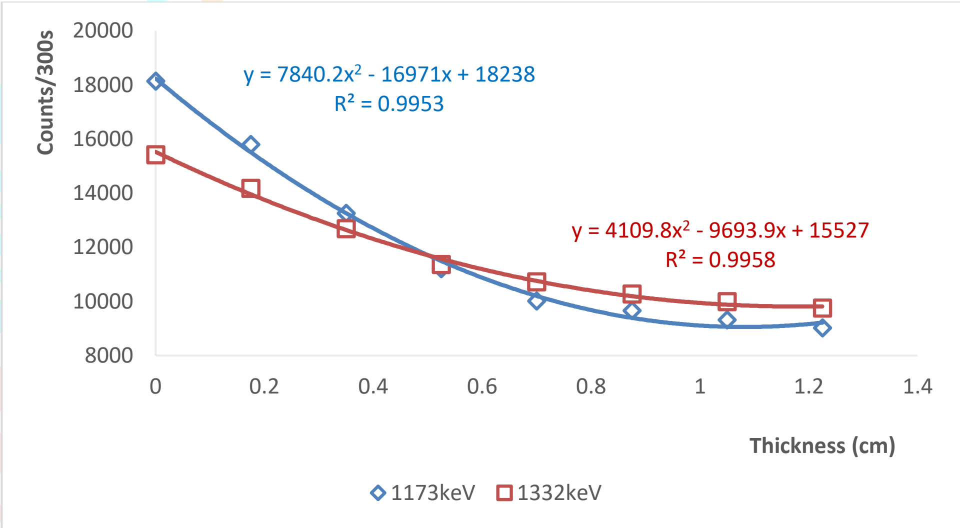

Fig 11. Count rate and absorber thickness of lead for 1173 and 1332 keV

Table 2. Calculated data for Carbon and Lead of attenuation coefficients

Energy (keV)	linear attenuation coefficient (cm^{-1})		mass attenuation coefficient (cm^2/g)	
	Absorbers		Absorbers	
	Lead	Carbon	Lead	Carbon
511	1.79195	0.16922	0.15858	0.08255
662	1.36115	0.15989	0.12045	0.07799
1173	0.79724	0.11854	0.07055	0.05782
1332	0.64777	0.102218	0.057326	0.049863

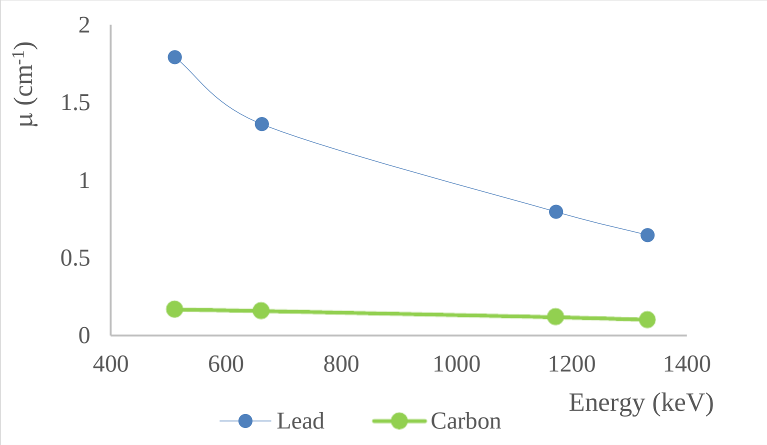

Fig 12. The plot of linear attenuation coefficient v/s energy for lead and carbon

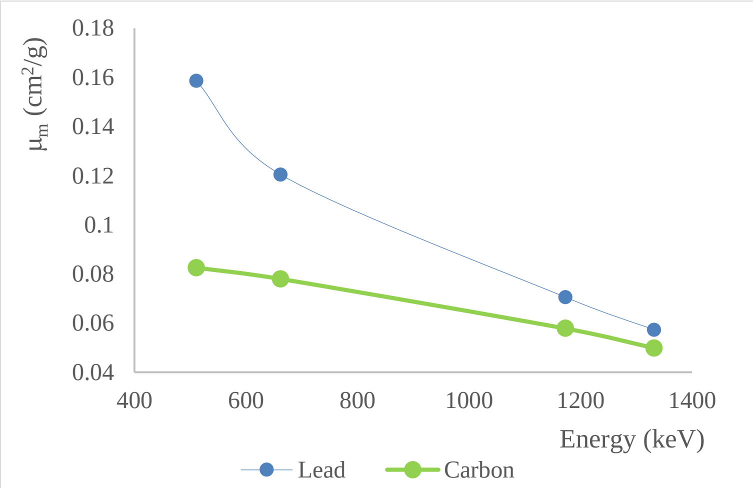

Fig 13. The plot of mass attenuation coefficient v/s energy for lead and carbon

Figure (12) and (13) represent the variation of linear and mass attenuation coefficients as a function of photon energies for carbon and lead. From these, the attenuation coefficients of the lead element under investigation decrease exponentially as photon energy increases. The carbon element is doesn’t happen clearly.

Table 3. Calculated data for Lead and Carbon of HVL

Energy (keV)	Half value layer thickness (cm)	
	Absorbers	
	Lead	Carbon
511	0.3899249	4.1773872
662	0.5133057	4.4638035
1173	0.8973266	5.8808116
1332	1.1137450	6.7829874

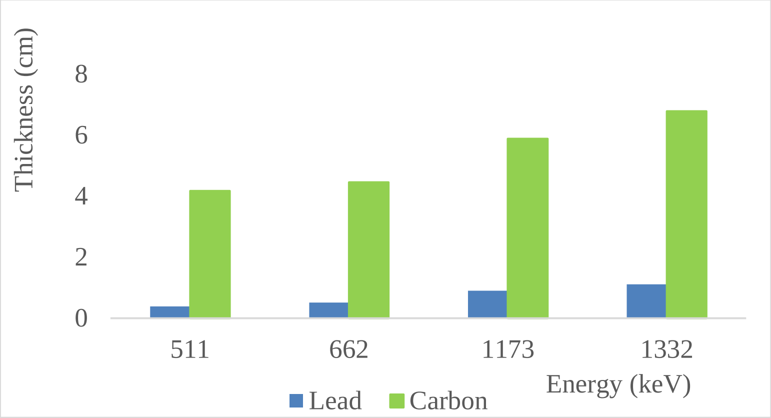

Fig 14. The plot of HVL thickness v/s energy for lead and carbon.

Figure (14) represents the variation of half - value layer thickness as a function of photon energies for carbon and lead. From this, the two elements of thicknesses are different clearly.

IV. Conclusion

In the present paper, the shielding parameters have been investigated and compared with carbon and lead. Lead is found to have a lower half-value layer thickness than carbon. Further, the mass attenuation coefficient of lead is higher than the carbon. The higher density and larger effective atomic number lead has the most effective attenuate ability than carbon. These findings suggest that the lead should be used to reduce the gamma radiation intensity as a shielding material. This work is useful for medical, health care, and radiation diametric applications.

V. Acknowledgment

We would like to express our profound thanks to Professor Dr U Win, Head of Department of Physics, and Dagon University for his kind permission to carry out this work and his encouragement during this work.

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