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EC EMERGENCY MEDICINE AND CRITICAL CARE
Research Article

Measurement of Mass Attenuation Coefficients of Gamma Rays in Copper

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Received: November 16, 2021; **Published:** December 30, 2021

Abstract

This study presents experimental method in order to determine the mass attenuation coefficient of a copper with different energy for 22Na and 137Cs sources. It is compared with two theoretical methods a graphic method and a transmission method. The method proposes to realize a numerical absorption calibration curve to process experimental results. The gamma-ray mass attenuation coefficients of copper absorber were determined experimentally at different gamma-ray energies and different copper thicknesses in order to investigate how the number of gamma photons and their energies affect the calculation of mass attenuation coefficients of the copper. The mass attenuation coefficients (pm) for copper (Cu) were measured in the -ray energy 22Na, 137Cs as sources. Well shielded detector (Nal (Tl) scintillation detector) was used to measure the intensities of the direct transmitted beams and any photon absorbed or scattered appreciably does not reach the detector if the detector is far away from the absorber. The measured values are compared with the theoretical values obtained by WINXCOM software.

Keywords: *Measurement; Attenuation Coefficients; Gamma Rays*

Introduction

Gamma rays play an important role in vast fields like in industry, medicine, military agriculture, research, space science, etc. It also plays an important role in many interdisciplinary fields. In all these fields -ray sources are used. These sources may be weak (low activity p Ci) or strong (with activity may be as large as thousands of Ci). In areas where humans are likely to encounter gamma rays, it is often necessary to provide proper shielding to reduce the risk of exposure to gamma rays.

Various types of shield have been developed using high density concrete, lead brills etc. The gamma ray attenuation of these materials has been widely studies and attenuation data is available such as the National institute of Standards and Technology (NIST) WINXCOM software. Composite materials such as lead wool, high density metals dispersed in organic polymers etc are finding more use as shielding materials.

The attenuation of -rays occurs through the interaction with matter. The degree to which gamma radiation is attenuated is dependent upon the energy of incident radiation, the atomic number and density of shielding materials and thickness of the shielding composite materials may offer additional benefits like chemical resistance, physical durability, etc., but due to non availability of composite materials, in the present work, attenuation of gamma rays has been studies natural copper. In this work, we evaluate the gamma-ray as a function of energy, for 0.511, 0.662, 1.275MeV, by using 137Cs and22Na radioactive sources [1].

In The present work, gamma radiation mass absorption coefficients of Copper using 22Na and 137Cs gamma sources are measured and reported in this work. These measurements were performed using the 10 x 10NaI (Tl) scintillation detector coupled to photo multiplier tube, preamplifier and amplifier. The signals from amplifiers were fed to the computer based multichannel analyzer (M.C.A) gamma ray spectrometry system for pulse height analysis [2].

The knowledge of gamma ray interaction mass attenuation coefficient of a material provides not only better understanding of the degradation of intensity but also a basis for safe handling of what might be admittedly harmful material.

The accurate determination of mass attenuation coefficients is essential before a given material is used in as gamma ray shield. Different other workers have calculated attenuation coefficients in different categories such as building materials, alloys, marbles, glasses, biological materials and other composite materials. Half value layer (HVL) is other useful parameters for understanding the interaction of gamma ray.

Many workers have studied HVL for shielding characteristics of materials [3]. When selecting the best shielding material for a particular source of radiation, it is important to understand the mechanisms through which the gamma radiation is attenuated. As discussed earlier the most important factors that determine the relative importance of the mechanisms through which gamma radiation is attenuated are (1) the energy of the gamma radiation and (2) the atomic number of the element(s) from which the shielding is constructed.

Three of most important mechanisms for gamma radiation are photoelectric absorption, Compton scattering and pair production [4]. The reduction of the intensity of a -ray beam as it traverses matter is attenuation. The reduction may be caused by absorption or by deflection (scatter) of photons from the beam and can be affected by different factors such as beam energy and atomic number of the absorber [5].

Several factors affect attenuation. Some are related to the -ray beam or radiation and the others to properties of the matter through which the radiation is passing. Some of them are factors affecting attenuation, effect of atomic number, effect of thickness effect of density and effect of gamma-ray energy [6-21].

Experimental measurement of mass attenuation coefficients of a material in our country is not practiced well. This may be because of lack of necessary instruments and radiation sources. Research on the measurement of mass attenuation coefficients is necessary designing radiation shield from the available local materials. As a first beginning on this area of research in Jimma University in this thesis, an attempt was made to experimentally determine the mass attenuation coefficient of copper. Gamma ray attenuation coefficients can also be used for thickness determination of this foil.

Methods and Materials

In this thesis experiment the following instruments would be used.

- Copper foils of different thicknesses.
- Gamma sources (22Na, 137Cs)

- NaI (TI) gamma ray detector.
- Multichannel Analyzer (MCA)
- High voltage power supply
- Measure software installed computer (MEASURE)
- Desktop Computer
- Flash disc, Stationary materials, and Printer
- Accessories References like journals, published articles and books.

Method of data analysis

Complete experimental setup used in the present experiment is shown in fig 3.1, on the experiment right hand side, NaI (Tl) detector is mounted vertically. Below the detector a well collimated gamma ray source is placed. The collimated is about 0.8 cm in diameter. Next to the detector is a unit which houses high voltage supply and a 4k multichannel analyzer.

Experimental procedure

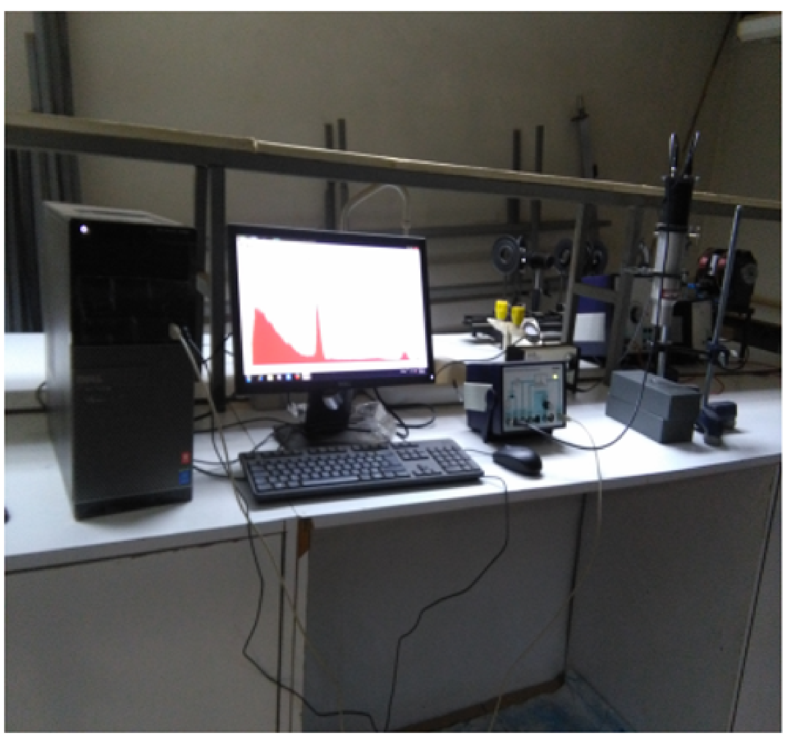

Figure 1: *Experimental set up.*

- Connect the gamma spectrometry and associated electronics.
- Set the time to 3600s and the detector operating to 550V.
- Record the count rate per one hour for the background.
- The procedure is to measure and record the count rate of detected gamma rays as function of the mass thickness of copper foil that are placed between the source and detector.
- On the multichannel analyzer (MCA) unit the mode switch would be set to present count by switching the toggle switch.
- The counter would be started on the MCA.
- In the computer using the measure software, start the acquisition of the spectrum.
- Record for one hour and save the spectrum.
- Repeat the procedure using 0.04cm, 0.08cm and 0,12cm thicknesses for copper foils.
- Using the measure software, analyze the intensity of the source with and without the foil.
- Take data of the analyzed intensities Io and I to calculate the mass attenuation coefficient of copper foil.

Experimental analysis

The measurements of the linear attenuation coefficient can be calculated by using the equation 2.23 and plot a graph between ln Io I and the thickness(x), if the relation is a straight line, then the attenuation law is stated and find the slope from the graph, and again find the negative of the slope from the graph, this is equal to the linear attenuation coefficient by using the density of copper(ρ = 8.96 g cm3) was done using1'×1' Nal (Tl) scintillation detector(model 38B51/2-x), using preamplifier, amplifier, and multichannel analyzer(model 13727-99), Measure software installed computer analysis was also used. Monoenergetic gamma rays, from 22N a (code: SKRB8151), and 137Cs (code: CDRB1187) sources were collimated into a narrow beam and allowed to strike a detector after passing through an absorbers of copper of variable thickness. The attenuation of the intensity received by the detector as the absorber thickness is increased measures the total probability per unit length of the interaction processes. The usual logarithmic plot of transmitted intensity, I, versus thickness of absorber, x, follows a straight line, indicating exponential decay of the intensity. The slope, μ, of the straight line represents attenuation coefficient, namely, the probability scattering, that a photon be removed from the incident beam per unit thickness of material traversed.

Experimental Result and Discussion

Gamma Ray spectrum of i37Cs with NaI (Tl) Detector

The gamma ray spectrometry was properly calibrated for energy using one photo peak of 137Cs at 662keV. Then first gamma ray spectrum of 137Cs was recorded for 3600sec without any absorber foil. This spectrum is shown in fig. 4.1. Then copper foil of thickness 0.04cm was placed between the detector and source. Again the spectrum was recorded for 3600 sec. Same steps we have for expected for copper foils of thickness 0.08 and 0.12 cm. The spectrum recorded with copper foil of thickness 0.12cm is shown in fig 4.2. This figure shows the gamma ray spectrum of 137Cs source (E = 0.662Mev) counted by NaI (Tl) detector coupled to M.C.A without copper foil. Figure 4.1 shows gamma ray spectrum of 137Cs source (E = 0.662 Mev) with copper absorber foil of thickness 0.12cm.

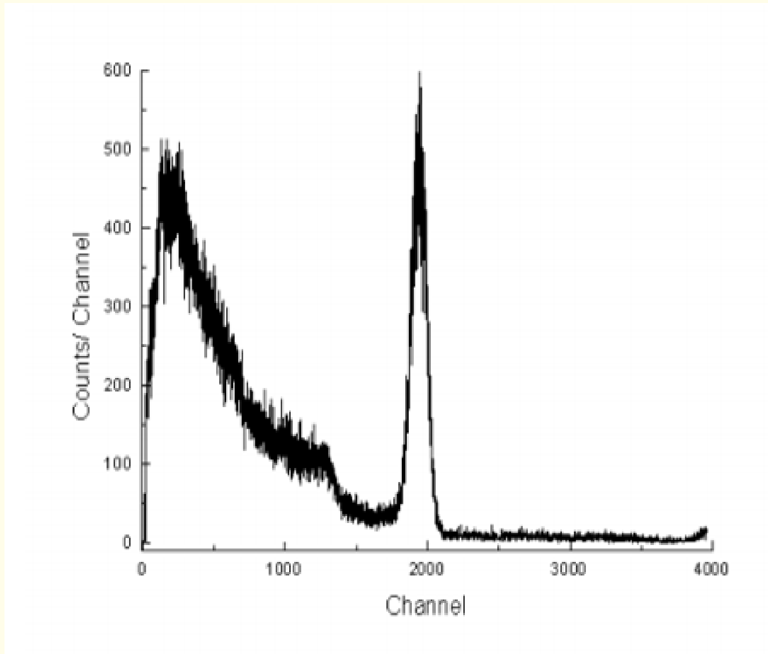

Figure 2: *Gamma Ray spectrum of 137 Cs with NaI (TI) detector without Cupper foil.*

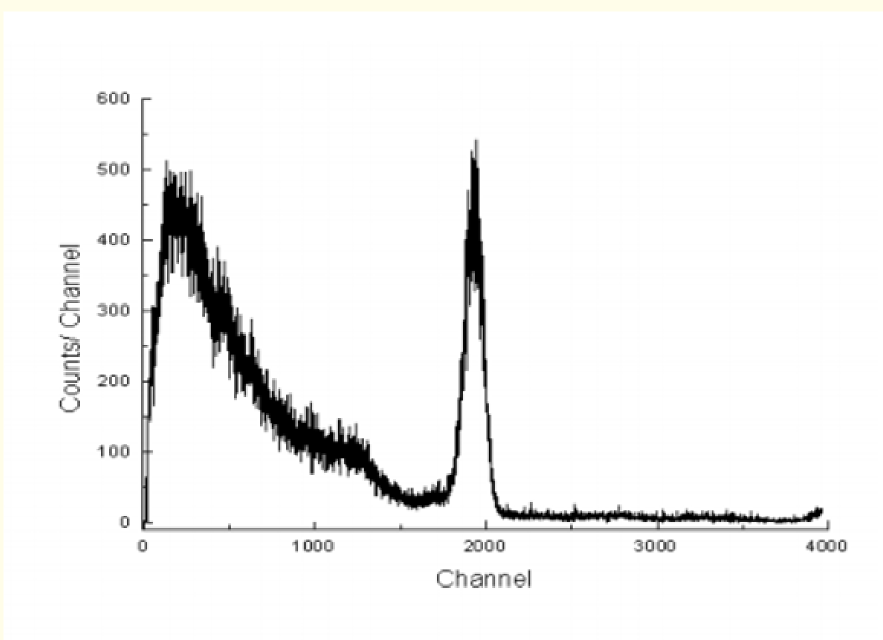

Figure 3: *Gamma Ray spectrum of 137Cs with NaI (Tl) Detector with thickness of 0.12cm.*

Gamma Ray spectrum of 22Na with NaI(Tl) Detector

The gamma ray spectrometry was properly calibrated for energy using two photo peak of 22Na at 551keV and 1274 keV. Then first gamma ray spectrum of 22Na was recorded for 3600sec without any absorber foil. This spectrum is shown in figure 4.

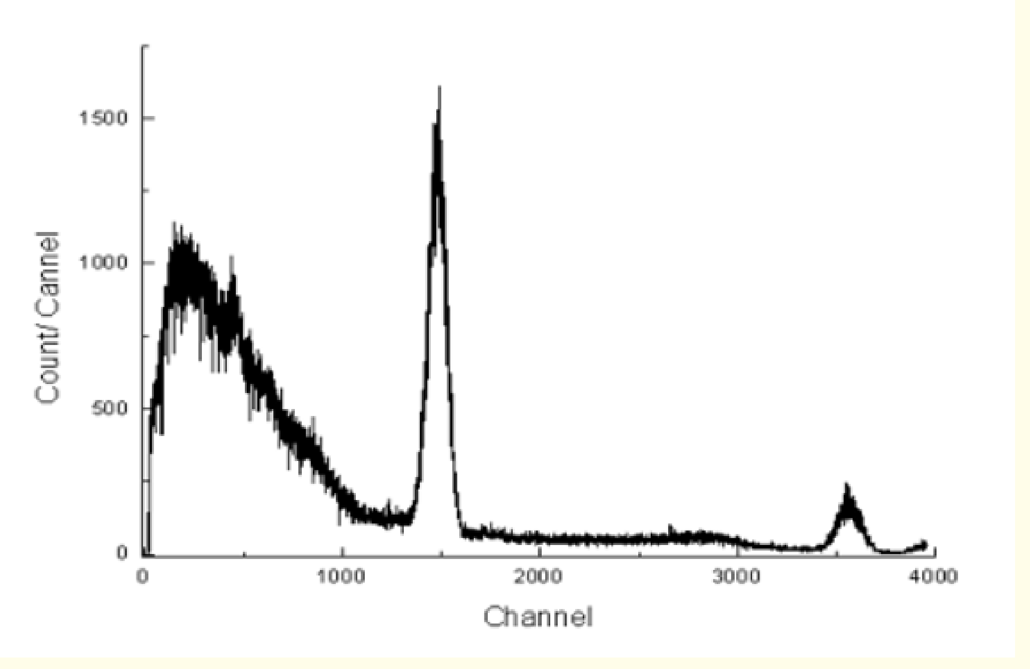

Figure 4: *Gamma Ray spectrum of 22Na with NaI (Tl) Detector without copper foil.*

Then copper foil of thickness 0.04cm was placed between the detector and source. Again the spectrum was recorded for 3600sec. same steps we have for expected for copper foils of thickness 0.08 and o.12cm. The spectrum recorded with copper foil of thickness 0.12cm is shown in figure 5.

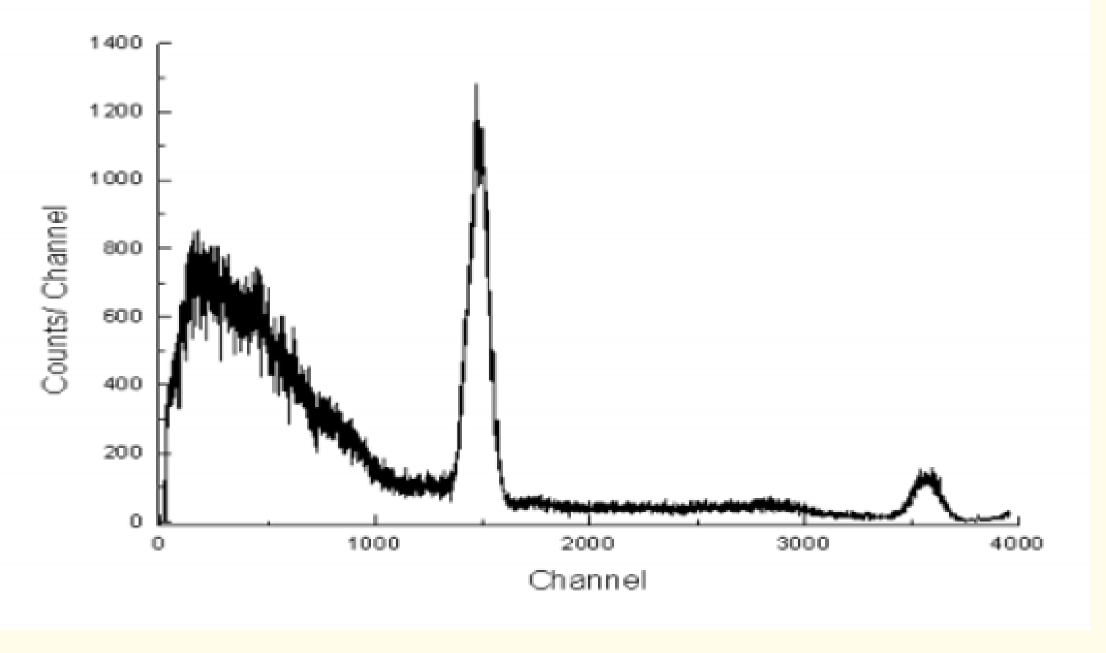

Figure 5: *Gamma Ray spectrum of 22Na with NaI(Tl) Detector with thickness of 0.12cm.*

Background gamma ray spectrum

As well as detecting radiation emitted from the radioactive source, all detector systems were register events that originate from the surrounding environment provided this is relatively constant; measurements of empty sources can be made to quantify the levels of background radiation expected. Before all experiments, background spectra were acquired (see figures 5). The room background was counted with an empty sources holder for 3600 seconds.

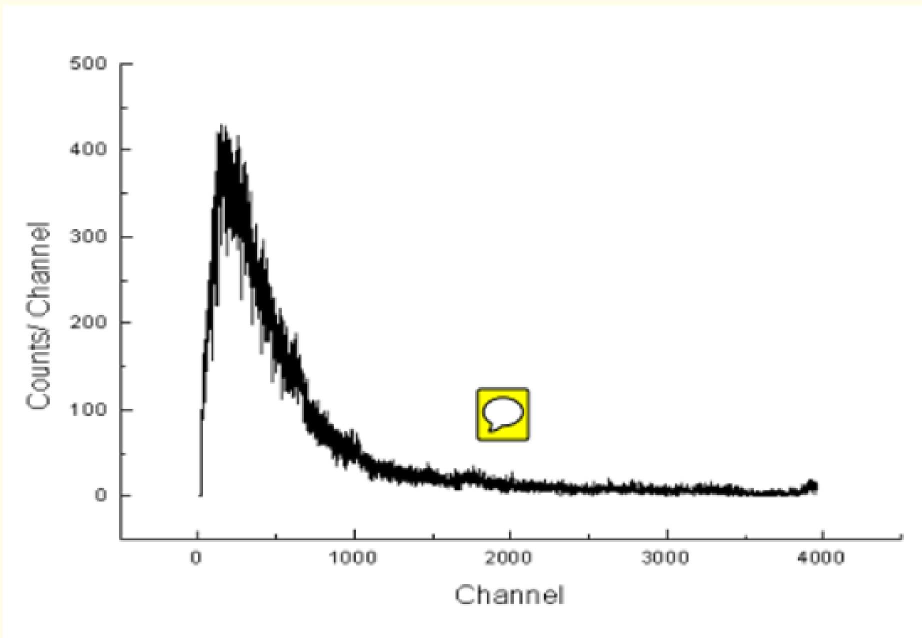

Figure 6: *Gamma ray Background Spectrum.*

Discussion for mass attenuation coefficient

The values of thicknesses in cm, transmitted intensity (I) and transmissions (ln *I*) are expressed for ^{137}Cs (662keV) in table 1, ^{22}Na (511keV) in table 2 and ^{22}Na (1274keV) in table 3.

I_o=5 I = 59448						
S Source	E Energy in kev	Ab Absorber	T T Thickness in cm	I II I	Io II Io/I	ln Io ln Io
			0.0 0.04	575 95	1. 1.03287	0.0 0.0323
^{132} ^{132}Cs	662 662	C Cupper	0.0 0.08	559 44	1. 1.0633	0. 0.06142
			0.1 0.12	542 77	1. 1. 0960	0. 0.0916

Table 1*: Thickness Vs ln I^0 for 662kev.*

I0=87799						
Source	Energy in kev	Absorber	Thickness in cm	I	Io I	ln Io
			0.04	84827	1.0350	0.0344
22 Na	511	copper	0.08	81796	1.0733	0.0708
			0.12	79100	1.1099	0.1043

Table 2: *Thickness Vs ln y for 511kev.*

Io=12699						
Source	Energy in kev	Absorber	Thickness in cm	I	Io I	ln Io
			0.04 89	12394	1.0246	0.0243
22 Na	1274	copper	0.08	12009	1.0575	0.0559
			0.12	11864	1.0704	0.0680

Table 3: *Thickness Vs ln I- for 1274kev.*

Transmission as a function of thickness in a copper samples at three different photo energies of gamma sources 137Cs (662kev) and22Na (511kev, 1274kev) are shown in figure 6.

(Table 2 and 3) experimentally measured values are in good agreement with the theoretically calculated values within acceptable experimental errors. It is clearly seen from figure 7 and 8 that the experimental values fall onto the theoretical curve computed by WINXCOM code and show a good agreement within the experimental error, and increasing photon energy causes the decrease of mass attenuation coefficient.

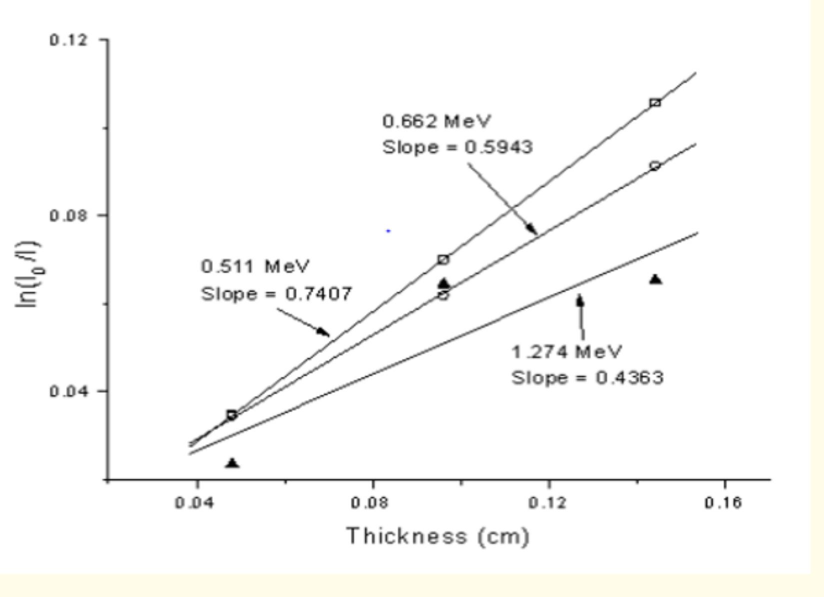

Figure 7: *Transmission as a function of thickness for copper for three different photon energies 137Cs (662kev) and 22Na (511kev , 1274kev).*

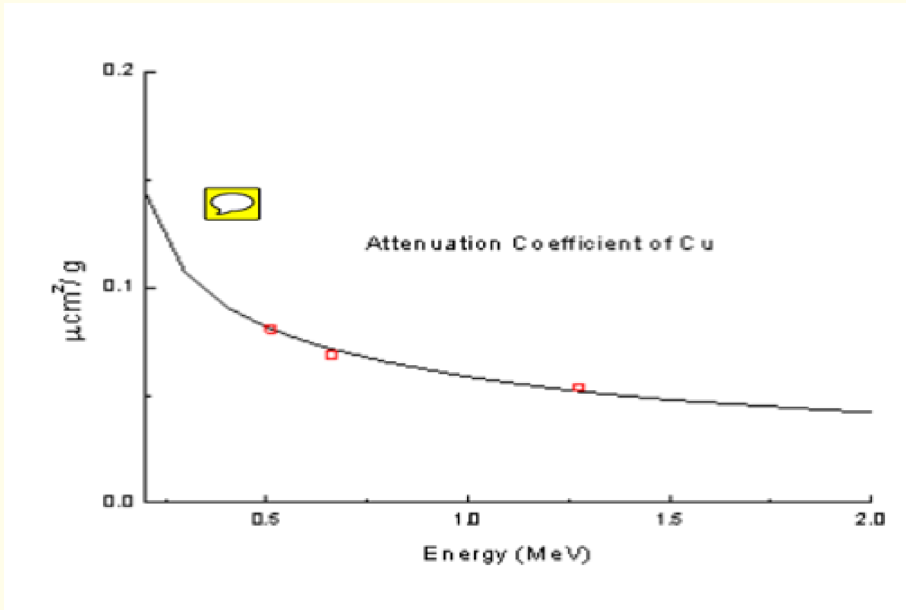

Figure 8: *Comparison of experimental and theoretical mass attenuation coefficients of copper as a function of photon energy.*

Conclusion

The mass attenuation coefficients for copper were measured in the gamma energy for 137Cs (0.662kev) and 22Na (0.511kev, 1.274kev) by using 1'×1' NaI (Tl) scintillation detector. The experimental values were compared with the theoretical data obtained by WINXCOM software. The comparison of the data showed good agreement between the obtained experimental values and theoretical values measured with WINXCOM Software. This shows that the method and experimental setup used by us can be successfully used for determination of linear and mass attenuation coefficients of any material, may be eliminated or composite. The attenuation properties of some copper have been evaluated and discussed in terms of mass attenuation coefficients at different gamma ray energies. The mass attenuation coefficients decrease with the increasing photon energy for these materials (Fig. 6). This is due to the different photon absorption mechanism for different photon energies. Mass attenuation coefficients of the studied copper were also determined computationally by using WINXCOM code. It is seen that experimental results are in good agreement with the theoretical results.

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Volume 6 Issue 1 January 2022