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Investigation of Gamma-Ray Attenuation Coefficients for Some Different Tissues

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Abstract

In this study, the half-value thicknesses, linear and mass attenuation coefficients of biological samples such as adipose tissue, bone, cardiac muscle, liver, lung, muscle skeletal and soft tissue have been measured at 97, 243.79, 344.89, 662, 778.43, 866.27, 962.31, 1112.87, 1173, 1333 and 1407.52 keV energies by using the NaI(Tl) spectrometer. The gamma-rays were obtained from ^{152}Eu, ^{137}Cs and ^{60}Co sources. Also theoretical calculations have been performed in order to obtain the half-value thicknesses, mass and linear attenuation coefficients, and the tenth-value thicknesses at photon energies 0.001 MeV–10 GeV for some tissues. The experimental linear mass attenuation coefficients, half value layer for tissue components were compared with theoretical values obtained using WinXCOM.

The half-value thicknesses, mass and linear attenuation coefficients, and the tenth-value thicknesses of tissue compounds have been computed in the wide energy region 1 keV to 10 GeV using an accurate database of photon-interaction cross sections and the WinXCom program. The linear attenuation coefficient for bone is higher than the tissues of cardiac muscle, liver, lung, skeletal muscle and soft tissue. HVL, TVL and mean free path are lower for bone than the tissues of cardiac muscle, liver, lung, skeletal muscle and soft tissue. The studied gamma dosimetric values for the relaxants are useful in medical physics and radiation medicine. Result shows that attenuation and required thickness to achieve certain attenuation power are highly photon energy dependent.

Keywords: Gamma Attenuation Coefficient, Half-Value Layer HVL, Tenth-value thickness TVL, Gamma Spectrometer

1. INTRODUCTION

Radiological safety of occupational radiation worker assumes significance with extensive use of radioactive materials in different fields [1-3]. The workers may encounter two kinds of exposure, internal & external [4]. On the other hand, the attenuation of gamma radiation in different materials and tissues is of general interest in many kinds of radiotherapy and clinical medical physics work [5-11]. The mass attenuation coefficient, μ/ρ, and the mass energy-absorption coefficient, μ_{en}/ρ, are basic quantities used in calculations of the penetration and the energy deposition by photons in biological, shielding and other materials [12]. The radiation attenuation, which occurs in the tissues located between the organs of interest and the detector, is one of the most important subjects in use of gamma rays in nuclear medicine. Therefore, measurements of half-value thicknesses of biological substances such as muscle, bone, lung, heart, fat and water are important. The linear attenuation coefficients (μ), defined as the probability of the photon interaction, in a particular way, with a given material per unit path length, and the related mass attenuation coefficients (μ/ρ) are also of great importance in matters concerning radiation and its absorption by matter such as radiation dosimetry.

The results of radiological measurements depend on whether the incoming radiation is absorbed, transmitted or scattered by the body organs and tissues [6]. In the radiation protection, certain tissues are thought to be more at risk from the harmfull effects of radiation. Tissues and organs may be considered when individual dose equivalents are being evaluated. Radiological techniques provide anatomical pictures based on the physical characteristics of the body structures [6]. Differences in the gene expression patterns have been studied in a tissue with absolutely uniform and equal dose-deposition [1]. Theoretical values for the mass attenuation coefficients can be found in the tabulation by Hubbell and Seltzer [13] Instead of interpolating from the tabulated values and using the mixture rule, using computer programs such as WinXCom. The letter program has been developed by Berger and Hubbell [14] for calculation of mass attenuation coefficients or photon interaction cross-section for any element, compound or mixture at energies from 1 keV to 10 MeV.

In this study, measurements have been made to determine radiation transmission, the linear and mass attenuation coefficients of more different tissues than previous studies by using ^{152}Eu, ^{137}Cs and ^{60}Co gamma ray sources. Half-value thickness, linear and mass attenuation coefficients were also calculated for adipose tissue, bone, cardiac muscle, liver, lung, skeletal muscle and soft tissue using the tables of Hubbell and Seltzer [13]. The experimental results were compared to the results of the WinXCom computer program.

2. METHODS AND MATERIALS

The adipose tissue, bone, cardiac muscle, liver, lung, muscle skeletal and soft tissue samples were obtained from a cow at different sample thicknesses.

2.1 Density measurement

The density measurements of the tissues were carried out with a precision scale to measure the weight M_A, and volume by using a vernier caliper. The density values were found to be the same as in the literature.

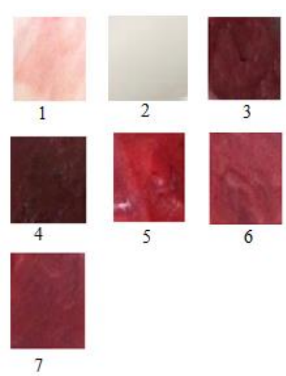

Figure 1. Some tissue samples (1 adipose tissue, 2 bone, 3 cardiac muscle, 4 liver, 5 lung, 6 skeletal muscle, 7 soft tissue)

2.2 Experiments

The gamma ray spectroscopy measurements were carried out at the Physics Department, Ondokuz Mayıs University, Samsun, Turkey and used 7.62×7.62 cm NaI(Tl) scintillation detector (Ortec-905-4).

The muscle, fat and bone samples were obtained from a cow at different sample thicknesses. The tissues were cut into about 4x4 cm slices. Also, the bone samples at different thickness were used in the experiment. The thickness of each sample was measured by using a micrometre. The linear attenuation coefficients were determined by performing transmission experiment in narrow beam geometry. The narrow beam was obtained by using the lead collimator (FIG 2). For this study, the diameter of collimator was adjusted to 30 mm. The samples were placed in between the γ-ray source and the NaI(Tl) detector. The detector absorbs a narrow beam of gamma rays passed through the sample. NaI(Tl) spectrometer system was used to count the signal of the transmitted gamma rays. In narrow beam geometry, the standard γ-point source was placed at a distance 175 mm away from each sample and 70 mm from the sample and detector as its shown in (FIG 2.).

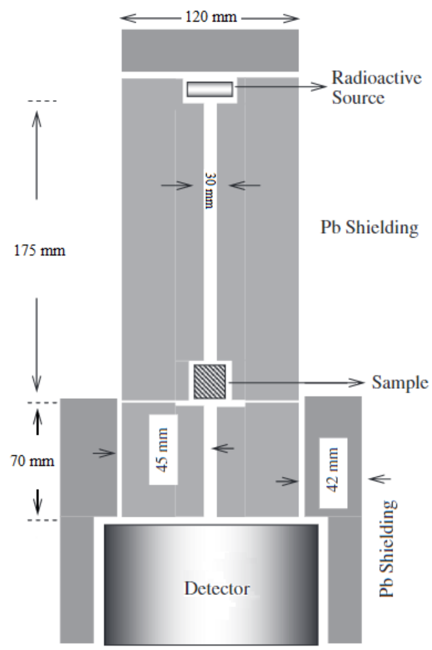

Figure 2. Mass attenuation coefficient measurement setup

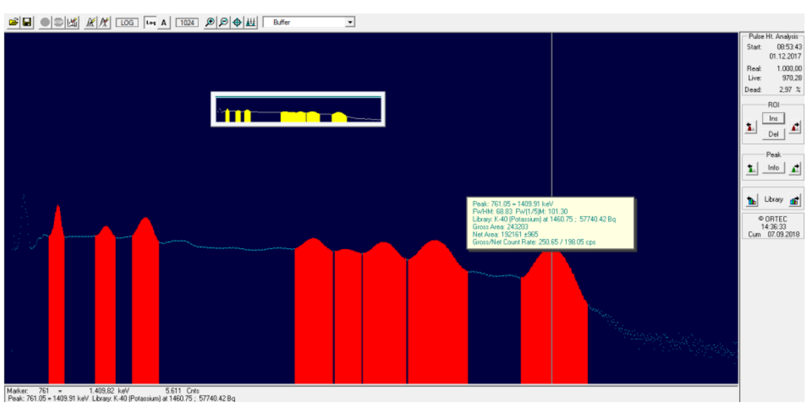

Figure 3. Energy spectrum of Eu-152 γ-rays, without sample

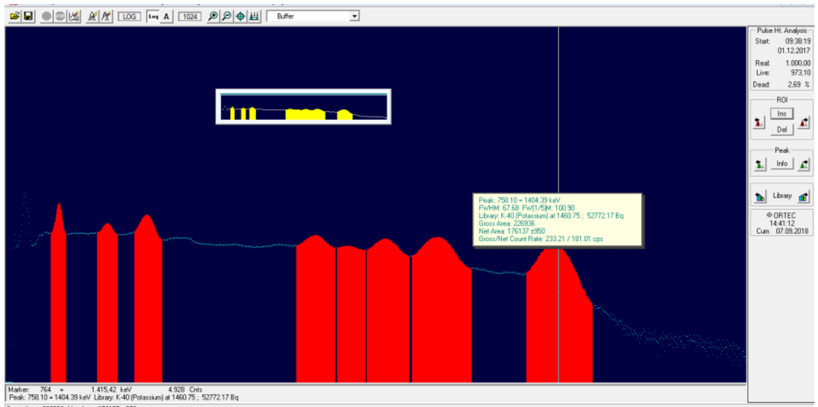

Figure 4. Energy spectrum of Eu-152 γ-rays, with sample

3. RESULTS

According to the Fig. 5 and Fig. 6, its clearly seen that the experimental and theoretical results are very relative. As we have studied many different tissues the calculated values for adipose tissue and bone was chosen to show as they represent lowest and highest density thorough human body tissues. In the following figure A represent the measurements with 137Cs and 60Co sources and B represent the measurements with Eu-152 source.

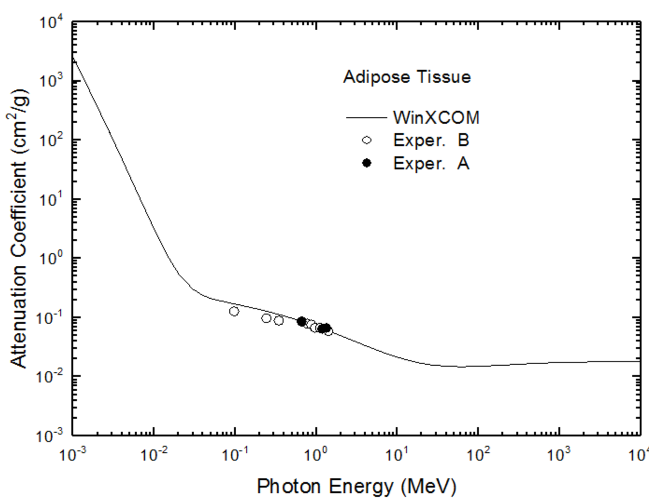

Figure 5. The experimental and calculated values of Attenuation coefficient for adipose tissue

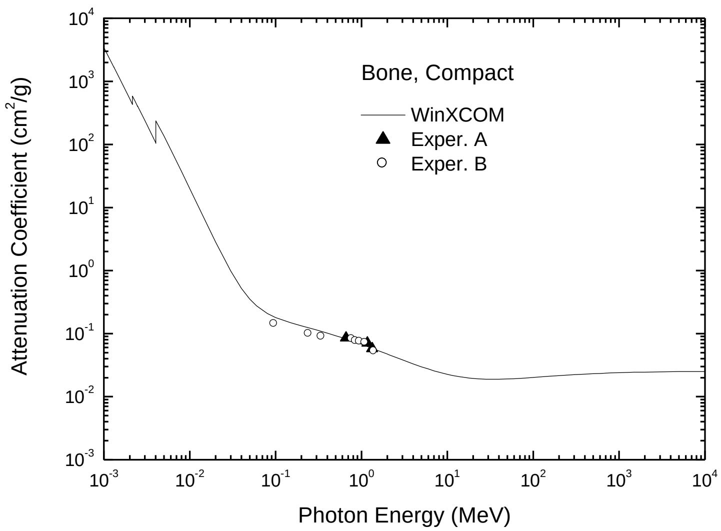

Figure 6. The experimental and calculated values of Attenuation coefficient for bone

The mass and linear attenuation coefficients values of the samples decrease with increasing photon energy. The experimentally and theoretically measured half-value thickness are shown in the following figures. The comparison between present experimental results and calculated values by using WinXCom shows that both results agreed well.

Problems of unacceptably high radiation dose to the patient in the radiological methods can be minimized by good estimation of the thicknesses of the tissues on the way of the radiation and careful choice of radiation source. Thus, it is provided that the patients are exposed to the less gamma radiation. Attenuation effect should be considered in treatment planning. This is important from the radiation safety points in view of dose calculations. However, it must be noted that the properties of the samples (the age, the part of body the sample was chosen, etc.) might not be exactly identical in different cases.

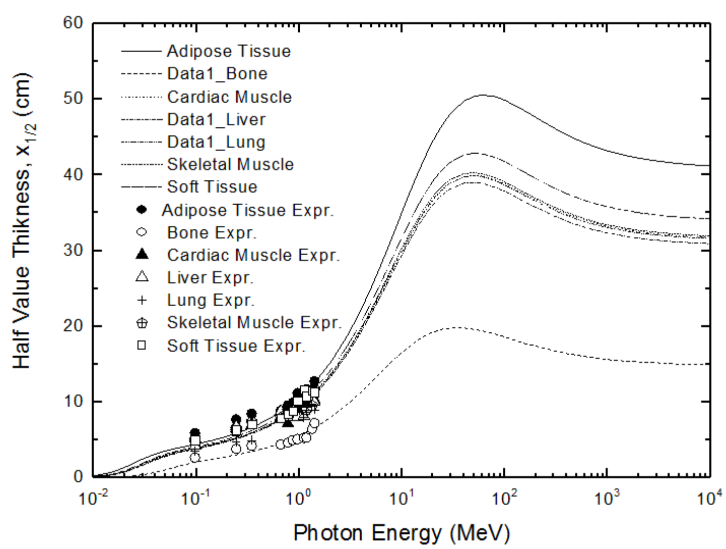

Figure 7. Experimental and calculated half value thickness, x1/2 for (adipose tissue, bone, cardiac muscle, liver, lung, muscle skeletal, soft tissue) and comparison with the experimental values (filled triangle data for μ)

4. CONCLUSION

The overall uncertainty in the measured values of the attenuation coefficients was estimated ≈ 2–4%. The errors in the present measurements are due to counting statistics, thickness determination and density measurement. The attenuation of gamma radiation from ^{137}Cs, ^{60}Co and ^{152}Eu has been studied experimentally, using narrow-beam geometry, in 7 different materials of interest in radiotherapy and in clinical radiophysics work.

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