T. R.
VAN YUZUNCU YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF PHYSICS

CALCULATION OF PHOTON INTERACTION PARAMETERS OF SOME BIOLOGICAL TISSUE

MASTER THESIS

PREPARED BY: Rawa Kamaran FATTAH
SUPERVISOR: Assoc. Prof. Dr. Rafet YILMAZ

VAN-2020

T. R.
VAN YUZUNCU YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF PHYSICS

CALCULATION OF PHOTON INTERACTION PARAMETERS OF SOME BIOLOGICAL TISSUE

M.Sc. THESIS

PREPARED BY: Rawa Kamaran FATTAH

VAN-2020

ACCEPTANCE and APPROVAL PAGE

This thesis entitled "**CALCULATION OF PHOTON INTERACTION PARAMETERS OF SOME BIOLOGICAL TISSUE**." presented by Rawa FATTAH under supervision of Assoc. Prof. Dr. Rafet YILMAZ in the department of physics has been accepted as a M. Sc. thesis according to Legislations of Graduate Higher Education on 21 / 01 /2020 with unanimity of vote's members of jury.

Chair: Prof. Dr. Koray KÖKSAL Signature:

Member: Assoc. Prof. Dr. Rafet YILMAZ Signature:

Member: Assoc. Prof. Dr. Berna OTO Signature:

This thesis has been approved by the committee of The Institute of Sciences on......./......../........ with decision number..................

Signature
Prof. Dr. Suat ŞENSOY
Director of Institute

THESIS STATEMENT

All information presented in the thesis obtained in the frame of ethical behavior and academic rules. In addition all kinds of information that does not belong to me have been cited appropriately in the thesis prepared by the thesis writing rules.

Rawa Kamaran FATTAH

ABSTRACT

CALCULATION OF PHOTON INTERACTION PARAMETERS OF SOME BIOLOGICAL TISSUE

FATTAH, Rawa Kamaran
M. Sc. Thesis, Physics Department
Supervisor: Assoc. Prof. Dr. Rafet YILMAZ
January, 2020, 66 pages

In this thesis study, the mass attenuation coefficients of some biological tissues (adipose tissue, lung tissue, muscle tissue, skeletal cartilage, skeletal cortical tissue, skin tissue, soft tissue) were calculated using WinXCom code program for total photon interaction in 1 keV-100 GeV energy range. The values of mass attenuation coefficient (μ_ρ) are measure of the photon's penetrationfor a substance at a given energy.Firstly,the values of the mass attenuation coefficient must be calculated to determine the effective atomic number and electron density of a material.Therefore, the mass attenuation coefficients (μ_ρ) of these biological tissues were determined from the WinXCom code in the 1keV-100GeV energy range.Then effective atomic number andelectron density were determined using those values.

In this study, graphs of mass attenuation coefficients, effective atomic number and the electron density were plotted against photon energy. The regions were detected that were dominated by photoelectric effect, incoherent scattering and pair production. The photoelectric effect was found to be dominant in the low energy range, incoherent scattering the center and pair production events in the higher energy range.For each of these three prevailing cases, the effective atomic number and electrondensities have been recalculated. Those parameters were plotted and analyzed against energy. Besides, an experimental study in lung tissue and skeleton was performed and compared with the theoretical value

Key words: Effective atomic number (Zeff), Electron density (Nell), Mass attenuation coefficients (μρ).

ÖZET

BAZI BİYOLOJİK DOKULARIN FOTON ETKİLEŞİM PARAMETRELERİN HESAPLANMASI

FATTAH, Rawa Kamaran
Yüksek Lisans Tezi, Fizik Anabilim Dalı
Tez Danışmanı: Doç. Dr. Rafet YILMAZ
Ocak 2020, 66 sayfa

Bu tez çalışmasında, bazı biyolojik dokuların(adipoz doku, akciğer dokusu, kas dokusu, iskelet kıkırdağı, iskelet kortikali, deri dokusu, yumuşak doku) 1keV-100 GeV enerji aralığında foton etkileşimparametreleri WinXcomprogramı kullanılarak hesaplandı. Bir maddenin kütle soğurma katsayısı (μ_ρ), verilen bir enerjide fotonun giriciliğinin bir ölçüsüdür. Bir dokunun, etkin atom numarasını ve electron yoğunluğunu hesaplamak için öncelikle kütle soğurma katsayısının değerleri hesaplanmalıdır. Bundan dolayı, 1keV-100GeV enerji aralığında, bu biyolojik dokuların WinXCom programından kütle zayıflama katsayıları (μρ) ile hesaplanmıştır. Daha sonra bu değerler kullanılaraketkin atom numarası ve elektron yoğunlukları hesaplanmıştır.

Bu çalışmada, enerjiye karşı, kütle soğurma katsayıları, etkin atom numarası, elektron yoğunluğu grafikleri çizildi.Fotoelektrik olay, Compton olayı ve çift oluşum olaylarının baskın olduğu bölgeler tespit edildi. Düşük enerji aralığında fotoelektrik olay, ortada Compton ve daha yüksek enerji aralığında çift oluşum olaylarının baskın olduğu görüldü. Bu üç baskın olayın herbiri için, etkin atom numarası ve elektron yoğunlukları tekrar hesaplandı.Enerjiye karşı grafikleri çizilerek analiz edildi. Yine ayrıca, bir enerjide, akçiğer dokusu ve kemik için deneysel çalışma yapıldı ve teorik değer ile karşılaştırıldı

Anahtar kelimeler: Etkin atom numarası, Elektron yoğunluğu. Kütle soğurma katsayısı,

ACKNOWLEDGEMENT

I offer my great thanks to my instructorAssoc. Dr. Rafet YILMAZfor the help and support he had spared, for me during this study as the Master thesis I submit.

Iwould like to thank the head of department Prof. Dr. Harun AKKUŞ, for giving any kind of support at YYU, Faculty of Science, Department of Physics,

I would like to thank my husband (Rawaz Akram Abdullqadir) to help and supporting me to get master degree and writing my thesis.

I would like to thank my parents (Kamaran fatah and Berevan Masum), brother (Ramyar) and sister (Rawen) to help and supporting me to get master degree.

I would like to thank Assoc. Dr. Berna OTO, for giving any kind of support and giving me permission to use the WinXCom code programs during my theoretcal work, at YYU, Department of Marine Engineering, Faculty of Maritime,

I would like to thank the head of department Assist Prof. Dr. Tahir ÇAKIR, for help me at YYU, Department of Biophysics, and Faculty of Medical.

Iwould like to thank the Yuzuncu Yil University, Department of Physics instructor members and academic staff for their unsparing moral and support.

January / 2020

RawaKamaran FATTAH

TABEL OF CONTENTS

Page

ABSTRACT i
ÖZET iii
ACKNOWLEDGEMENT v
TABEL OF CONTENTS vii
LIST OF TABLES ix
LIST OF FIGURES xi
SYMBOLS AND ABBREVIATIONS xiii
1. INTRODUCTION 1
2. LITERATURE REVIEW 3
3. THEORITICAL INFORMATION 5
3.1. Electromagnetic Wave 5
3.2. Photon 5
3.3. X-Ray 6
3.4. Attenuation Coefficients 7
3.5. Effective Atomic Number 8
3.6. Effective Electron Density 9
3.7. Photoelectric Effect 9
3.7.1. Probability of interaction: 9
3.8. Incoherent Scatter 10
3.8.1. Probability of interaction is proportional to electron density: 10
3.9. Pair Production 11
4. MATERIALS AND METHODS 13
4.1. Theoretical Calculates 13
4.2. Biological Tissues 15
4.3. WinXCom Program 17
4.4. Experimental Measuremetnts 18

Page

5. RESULTS AND DISCUSSION 21
6. CONCLUSION 41
REFERENCES 43
EXTENDED TURKISH SUMMARY (GENİŞLETİLMİŞ TÜRKÇE ÖZET) 45
CURRICULUM VITAE 55

LIST OF TABLES

Table **Page**

Table 4.1. Biological Tissues…………………………………………………………..16

Table 4.2. Expermintal calculation………………………………………………………..18

Table 4.3. Theoritical calculation ……………………………………………………...19

Table 5.1. Mass attenuation coefficient (cm^2/g) to WinXcom results…………………22

Table 5.2. Effective atomic numbers (Z_{eff}) to WinXCom code program for mass attenuation coefficient………………………………………………………..22

Table 5.3. Electron density (N_{ell}) WinXCom code program for mass attenuation coefficient……………………………………………………………….23

Table 5.4. Effective atomic numbers for the adipose tissue to WinXCom code programfor photoelectric, incoherent scattering and pair production..……23

Table 5.5. Effective atomic numbers for the lung tissue to WinXCom code program for Photoelectric, incoherent scattering and pair production……24

Table 5.6. Effective atomic numbers for the muscle tissue to WinXCom code program for photoelectric, incoherent scattering and pair production ……25

Table 5.7. Effective atomic numbers for the skeleton cartilag to WinXCom code program for photoelectric, incoherent scattering and pairproduction……..25

Table 5.8. Effective atomic numbers for the skeleton cortical to WinXCom code program for photoelectric, incoherent scattering and pair production ……26

Table 5.9. Effective atomic numbers for the skin tissue to WinXCom code program for photoelectric, incoherent scattering and pair production …....26

Table 5.10. Effective atomic numbers for the soft tissue to WinXCom code program for photoelectric, incoherent scattering and pair production …………………27

Table 5.11. Electron density (N_{el}) for the adipose tissue to WinXCom code program for photoelectric, incoherent scattering and pair production ……27

Table 5.12. Electron density (N_{el}) for the lung tissue to WinXCom code program for photoelectric, incoherent scattering and pair production …....28

Table 5.13. Electron density (N_{el}) for the muscle tissue to WinXCom code program for photoelectric, incoherent scattering and pair production …....28

Table **Page**

Table 5.14. Electron density (N_{el}) for the skeleton cartilag to WinXCom code program for photoelectric, incoherent scattering and pair production …....29

Table 5.15. Electron density (N_{el}) for the skeleton cortical to WinXCom code program for photoelectric, incoherent scattering and pair production …....29

Table 5.16. Electron density (N_{el}) for the skin tissue to WinXCom code program for photoelectric, incoherent scattering and pair production ……30

Table 5.17. Electron density (N_{ell}) for the soft tissue to WinXCom code program for photoelectric, incoherent scattering and pair production ……30

LIST OF FIGURES

Figure **Page**

Figure 3.1 Electromagnetic wave…………………………………………………………..5

Figure 3.2 Cheast X-Ray…………………………………………………………...7

Figure 3.3 Photoelectric effect………………………………………………………10

Figure 3.4 Incoherent scatter………………………………………………………...11

Figure 3.5 Pair production ………………………………………………………..12

Figure 4.1 WinXCom computer program……………………………………………17

Figure 4.2 WinXCom compounding with computer program…………………………18

Figure 5.1Variation of the total mass attenuation coefficient (cm2/g) versus photon energy occurring for some biological tissue at an energy range (0.001MeV–10000MeV)…………………………….....31

Figure 5.2 Effective atomic numbers (Z_{eff}) versus energy (MeV)…………………..…32

Figure 5.3 Electron density (Nell) versus energy (MeV)……………………………32

Figure 5.4 Effective atomic numbers (Z_{eff}) of adipose tissue versus energy (MeV)…...33

Figure 5.5 Effective atomic numbers (Z_{eff}) of lung tissue versus energy (MeV)……....34

Figure 5.6 Effective atomic numbers (Z_{eff}) of muscle tissue versus energy (MeV)…....34

Figure 5.7 Effective atomic numbers (Z_{eff}) of skeleton cartilag versus energy (MeV)...35

Figure 5.8 Effective atomic numbers (Z_{eff}) of skeleton cortical versus energy (MeV)...35

Figure 5.9 Effective atomic numbers (Z_{eff}) of skin tissue versus energy (MeV)............36

Figure **Page**

Figure 5.10 Effective atomic numbers (Z_{eff}) of soft tissue versus energy (MeV)…….36

Figure 5.11 Electron density (N_{ell}) of adiposeversus energy (MeV)………………..….37

Figure 5.12 Electron density (N_{ell}) of lung tissue versus energy (MeV)…………..…...37

Figure 5.13 Electron density (N_{ell}) of muscle tissue versus energy (MeV)…………….38

Figure 5.14 Electron density (N_{ell}) of skeleton cartilag versus energy (MeV)…………38

Figure 5.15 Electron density (N_{ell}) of skeleton cortical versus energy (MeV)…………39

Figure 5.16 Electron density (N_{ell}) of skin tissue versus energy (MeV)……………….39

Figure 5.17 Electron density (N_{ell}) of soft tissue versus energy (MeV)………………..40

SYMBOLS AND ABBREVIATIONS

Along with a description of some symbols and abbreviations used in this study are presented below:

SYMBOLS	**Descriptions**
μ_ρ	Mass attenuation coefficient
Z_{eff}	Effective atomic number
N_{el}	Electron density
α	Alpha particle
β^-	Beta particle
n^0	Neutron particle
E_k	kinetik energy of the electron
E_b	Binding energy of the orbital
Z	Atomic number
μ (cm^{-1})	Linear attenuation coefficient
τ	Photoelectric effective absorbing
σ	Comptonscattering
N_A	Avagadro number
A	Atomic number
f_i	Fractional abundance
σ_m	Total molecular cross-section
σ_a	Total atomic cross-section
σ_e	Total electronic cross-section

1. INTRODUCTION

The researchers have recently focused on the studying of photon interaction parameters such as photon interaction cross section in materials, effective atomic number and electron density. This is due to increasing use of radioactive sources in a variety of different fields such as medicine, tomography, gamma-ray fluorescence studies, radiation biophysics, the nuclear industry, space research applications and in agriculture, etc. Using radiation in many different fields brings shielding problems as radiation can be hazardous for human cell. Thus, choosing a material becomes important in the radiation shielding processes. The interaction of photon with the matter depends on the incoming photon energy and atomic number of the material used shielding. Those quantities can be represented as mass attenuation coefficients (μ_ρ), effective atomic number (Z_{eff}) and electron number (N_{ell}).

The mass attenuation coefficient (μ_ρ) is a measure of the average number of interactions between incident photons and matter that occur in a given mass per-unit area thickness of the substance encountered. Mass attenuation coefficient values are important in fundamental physics and in many medical applied fields, the accurate (μ_ρ) values for photon in several materials are essential for some fields such as nuclear and radiation physics, radiation dosimetry, biology, medicine, agriculture, environment and industry. There have been done experimental and theoretical investigations to determine (μ_ρ) values in various elements and compounds. Significant information and problems associated with the measurement of X-ray attenuation coefficients can be seen Creagh and Hubbell's study (1987). The calculated values for the mass attenuation coefficients have been tabulated by Hubbell and Seltzer (1995). The atomic number of a composite material consisting of elements with different atomic numbers interacting with photon is characterized by a parameter called the "active atomic number". This number in composite substances is called as the effective atomic number (Z_{eff}) and varies dependence photon energy (Guru et al. 1998). Also, important parameter calculated in photon interaction studies is electron density (N_{el}). The electron density is determined as the number of electrons per unit mass of the composite material. The values of Z_{eff} depend on the incoming photon energy as well as the atomic number of the constituent elements in the material. The values for μ_ρ are unique for elements, compounds and mixtures, and are closely correlated to the effective atomic numbers of the interacting matter via their dependency on the cross-sections that result from the photon interaction with the matter. Hine (1952) expressed in the work that the effective atomic number of material containing various elements for photon interaction does not have a single value. Berger and Hubbell (1999) have used developed the XCOM code program for photon cross sections calculations. The program calculates photon interaction cross-sections and attenuation coefficients for element, compound or mixture, at energies from 1 keV to 100 GeV. After, a new Windows version of XCOM has been developed by Gerward et al., (2001) called WinXCom and this important program have made it possible to calculate mass attenuation coefficients with accuracy for wide ranges of photon energy and elemental composition. Manohara et al., (2008) have got the important work on the effective atomic number and electron density; a comprehensive set of formulas for all types of materialsand energies above 1 keV, and the effective atomic numbers of some biomolecules calculated by two methods; comparative study on theoretical computation.

The aime of present study is to investigate the mass attenuation coefficients, effective atomic numbers and electron densities of some biological tissuefor all photon interactions (photoelectric, incoherent scattering and pair production) in the energy range 1 keV-100 GeV. For this study, WinXComprogram were used. The effective atomic numbers and electron densities were calculated using the mass attenuation coefficients of some biological tissue obtained from the program in this energy range. The variations of effective atomic number and electron density with energy were shown graphically for the all photon interactions.

2. LITERATURE REVIEW

The photon interaction parameters such as photon interaction cross- section in materials, effective atomic number and electron densityare very important in atomic, molecule, radiation physics research, non-destructive tests, medical research.

Manohara and Hanagodimath (2007) calculated effective atomic numbers and electron densities for some amino acids using the WinXCom programin the 1 keV to 100 GeV energy range. In this sudy, the values of these parameters have been found to change with energy and composition of the amino acids.

Gowda et al. (2005), the effective atomic numbers and electron density of some amino acids determined theoretically and experimentally in a few photon energies

Sidhu et al. (2012) calculated the mass attenuation coefficients of the compounds containing H, C, N and O elements by using 59.54 keV energy gamma rays from 100 mCi Am-241 radioactive sources.

Singh et al (2002) calculated gamma-ray attenuation coefficients for bismuth Borate Glasses.

Chantler et al. (2001) studied the measurement of the X-ray mass attenuation coefficient of copper using 8.85–20 keV synchrotron radiation.

Limkitjaroenporn etal. (2011) Investigated gamma-ray shielding properties of lead sodium borate glasses.

Manjunathaguru and Umesh (2006) calculated the effective atomic number and electron densities of the compounds containing H, C, N and O in the 145 -1330 keV energy range.

Kumar (2016) calculated the effective atomic number and electron densities of the some compounds containing H, C, N, O and P.

Kumar et al (2007).Studied on effective atomic numbers and electron densities in some.

Demir and Turşucu (2012) calculated the mass attinuation coefficients, mass energy absorption coefficients and kerma values of some vitamins by using 356, 61, 661, 66, 1250 and 1408, 01keV gamma energies.

Akar et al. (2006), measured the mass attinuation coefficients of biological samples such as bone, muscle, fat and water at gamma energy 140, 364 and 662 keV.

Akkurt, et al (2010). Gamma-ray shielding properties of concrete including barite at different energies.

Akkurt (2007, 2008, 2009) studied on the effective atomic numbers of various substances at different energies.

Işikli and Oto (2017) calculated gamma or X-rays attenuation properties of some biochemical compounds.Icelli et al (2005) studied on the Linear mass attenuation coefficient of Ni based alloys at energies 42.0 KeV and 59.54 KeV

Same way, some researchs have done studies on mass attenuation coefficients (μ_ρ), effective atomic number (Z_{eff}) and effective electron density (N_{el}) for different material types. (Çevik 2005, 2006, Kıran et al, 1996, İcelli et al. 2005, Murty et al., 2004, Kumar 2016, Sing et al 2013 , Jackson et al 1981).

3. THEORITICAL INFORMATION

3.1. Electromagnetic Wave

Electromagnetic radiation is one of the many ways that energy travels through space. The heat from a burning fire, the light from the sun, the X-rays used by your doctor, as well as the energy used to cook food in a microwave are all forms of electromagnetic radiation. While these forms of energy might seem quite different from one another, they are related in that they all exhibit wavelike properties.

EM waves travel with a constant velocity of 3.00 x 10^8 ms^{-1} in vacuum. They are deflected neither by the electric field, nor by the magnetic field. However, they are capable of showing interference or diffraction. An electromagnetic wave can travel through anything, a solid material or vacuum. It does not need a medium to propagate or travel from one place to another.

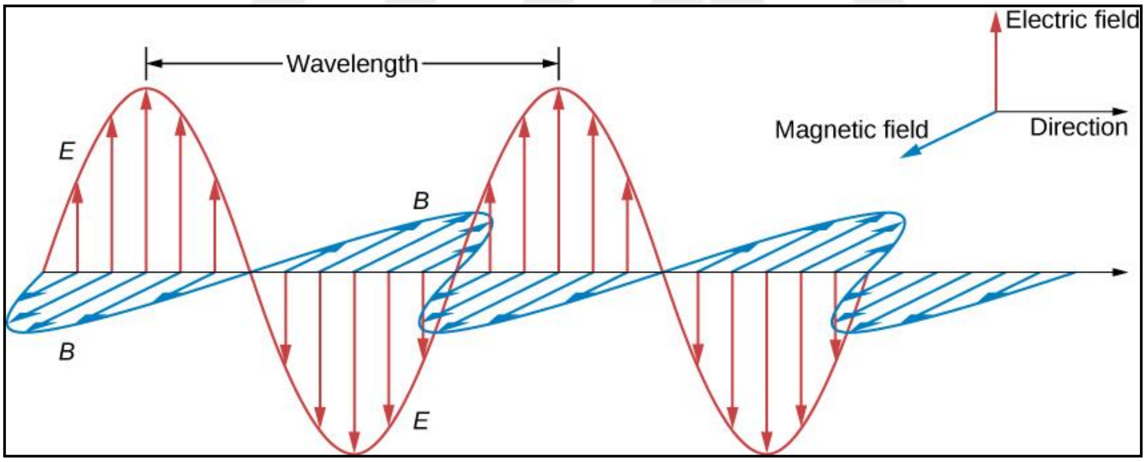


Figure 3.1 Electromagnetic wave.

3.2. Photon

A photon is the elementary particle, or quantum, of light. As we will soon see, photons can be absorbed or emitted by atoms and molecules. When a photon is absorbed, its energy is transferred to that atom or molecule. Because energy is quantized, the photon's entire energy is transferred (remember that we cannot transfer fractions of quanta, which are the smallest possible individual "energy packets"). The reverse of this process is also true. When an atom or molecule loses energy, it emits a photon that carries energy exactly equal to the loss in energy of the atom or molecule. This change in energy is directly proportional to the frequency of photon emitted or absorbed. This relationship is given by Planck's famous equation:

$$E = h\upsilon$$

Where E is the energy of the photon absorbed or emitted (given in Joules, J), υ is frequency of the photon (given in Hertz, Hz), and h is Planck's constant, $6.626\text{x}10^{-34}$J.s.

3.3. X-Ray

X-rays are electromagnetic radiation of exactly the same nature as light but of very much shorter wavelength.

X-rays are types of electromagnetic radiation probably most well-known for their ability to see through a person's skin and reveal images of the bones beneath it. Advances in technology have led to more powerful and focused X-ray beams as well as ever greater applications of these light waves, from imaging teensy biological cells and structural components of materials like cement to killing cancer cells.

It is roughly classified into soft X-rays and hard X-rays. Soft X-rays have relatively short wavelengths of about 10 nanometers (a nanometer is one-billionth of a meter), and so they fall in the range of the electromagnetic (EM) spectrum between ultraviolet (UV) light and gamma-rays. Hard X-rays have wavelengths of about 100 picometers (a picometer is one-trillionth of a meter).

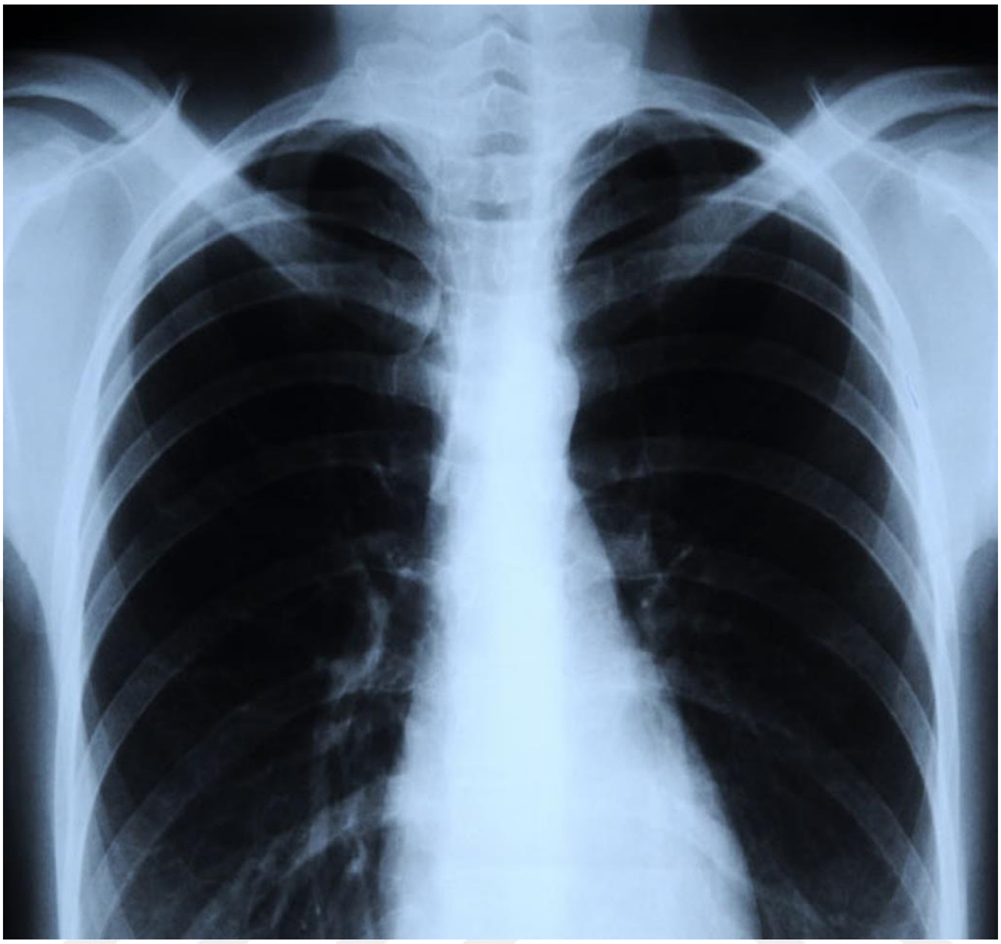


Figure 3.2 Cheast X-Ray.

3.4. Attenuation Coefficients

Absorption: Loss of photons from a beam due to photon energy beingabsorbed by matter.

Scatter: Loss of photons from a beam due to photons changing direction.

Attenuation: Loss of photons from Absorption AND Scatter.

Linear attenuation coefficient (μ): (Measures the rate at which photons are attenuated per centimeter of material encountered)

Mass attenuation coefficient (μ_ρ): is the linear attenuation coefficient divided by the density of the attenuating material. This is used for calculations such as “how much mass is needed for shielding?”

When a narrow beam of incident intensity I_0 passes through a homogeneous absorber of the thickness (cm), then according to Lambert's Beer Law, the emerging photon intensity (I) given by

The following expression:

$$I = I_0 e^{-\mu x} = I_0 e^{-(\mu/\rho)d}$$

Where μ (cm^{-1}) is the linear attenuation coefficient foramaterial of mass density ρ (g/cm^3) and atomic number Z.The mass attenuation coefficient has the advantage of beingin dependent from the materialdensity.If the absorber is achemical compound oramixture, its mass attenuation coefficient μ/ρ can be approximatelyevaluated from the coefficients μ_i and ρ_i for the constituent elements according to the weighte daverages

$$(\mu/\rho)_C = \sum w_i (\mu/\rho)_i$$

Where W_i is the proportion by weight of the ith constituent

3.5. Effective Atomic Number

The atomic number for composite materials interact with a photon is called as, effective atomic number Z_{eff}, The effective atomic number is calculated from atomic numbers of the constituent elements.

The effective atomic number of a complex materal is calculated using the following equation:

$$Z_{eff} = \frac{\sum fi\, Ai\left(\frac{\mu}{\rho}\right)}{\sum fi\frac{Ai}{zi}\left(\frac{\mu}{\rho}\right)}$$

Where $\boldsymbol{f}_i$is the fraction by mole of each constituent element provided that $\sum \boldsymbol{f}_i$ =1A is the atomic weight. Z is the atomic number and (μ/ρ) is the mass attenuation coefficient.

3.6. Effective Electron Density

The effective electron density: it is defined as the electrons per unit mass of the absorber as reported earlier .Effective electron density can be expressed by the following relation.

$$N_{ell} = N_A \frac{Zeff}{<A>} \ (Electrons/g)$$

Where $<A>$ is the average atomic mass of the material

3.7. Photoelectric Effect

Photon interacts with an atom and causes it to eject an electron or x-rayWith a nice new comfortable position available, a less comfortable electron will take its place. It is occurs at energies (1–150 keV) Dominant Interaction at (10–26 keV)

For photoelectric effect if incoming photon energy greater than the binding energy an inner electron knocks it completely out of the atom. The nice comfortable open spot means that higher energy electrons want to fill it and will therefore the extra energy in the form of an Auger electron or a characteristic x-ray.

3.7.1. Probability of interaction:

Probability ofphotoelectricinteraction is proportional to Z^3/E^3:

- Z^3 (Atomic number cubed): Happens way more in lead ($Z^{¼}$82) than water ($Z^{¼}$1 and 8 for H and O perspectively).
- $1/E^3$ (inverse Energy cubed): happens a lot at low energy and not at all with higher energies.

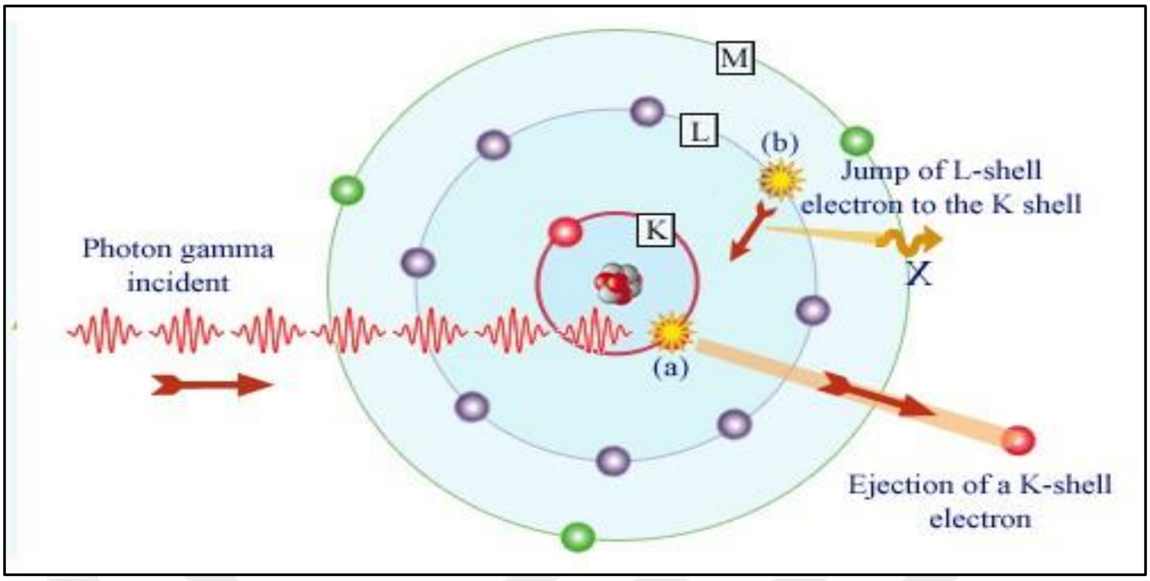


Figure 3.3 Photoelectric effect.

3.8. Incoherent Scatter

A scattering phenomenon between the photon and a charged particle such as an electron that causes momentum exchange between the photon and the electron, an incoming photon hits an electron and knocks it out of the atom like a cue ball hitting another ball. Part of the energy is transferred to the electron (which is then free to do damage by exerting coulombic forces) and the electron's new energy (plus the binding energy of the electron) is lost by the photon.

The photon literally hits an electron and it flies out of orbit with the photon being deflected as well.

3.8.1. Probability of interaction is proportional to electron density:

This is roughly proportional to mass density for most materials. Therefore, one gram of water is similar to one gram of fat or bone.

This is independent of Z and therefore less sensitive to bone, lead, and other higher-Z materials.

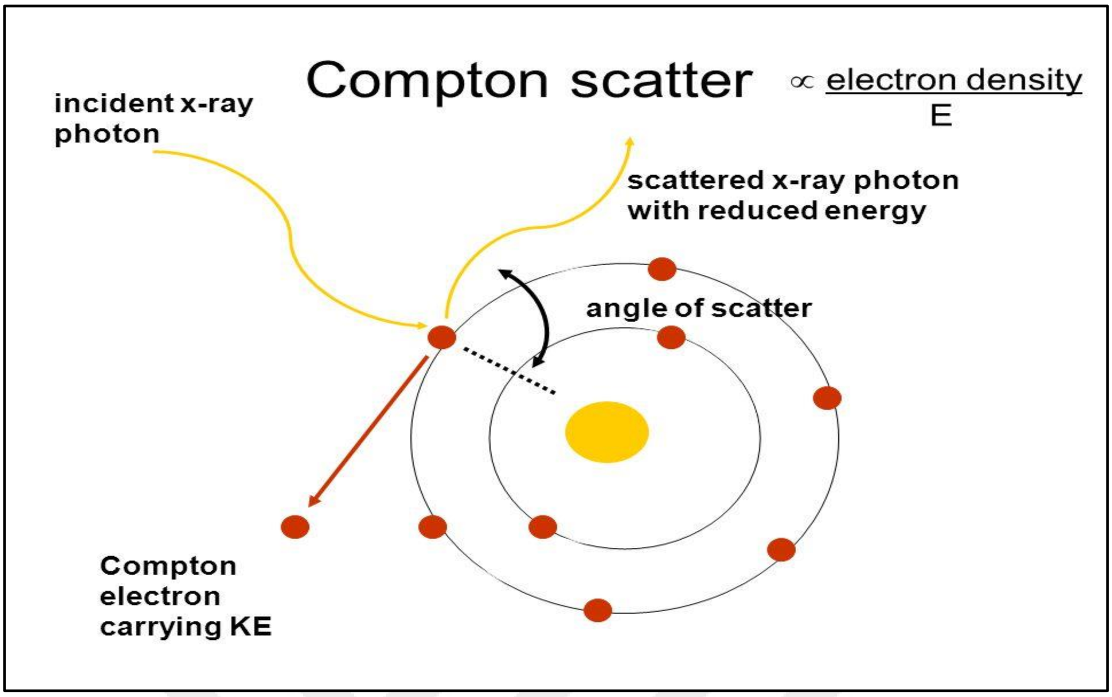


Figure 3.4 Incoherent scatter.

3.9. Pair Production

A photon is traveling with so much energy that when it hits the electric field of the electron orbitals, it explodes into an electron and a positron out of thin air.The electron wonders off and exerts coulombic forces but the positron not only causes ionizations by coulombic forces, but it eventually slows down and finds an electron somewhere else and annihilates it The resulting mutual anihilation sends two photons in opposite directions with an exact energy of 0.511 MeV.

• Occurs at energies of: 1.02 MeV and above.

• Dominant Interaction at: 10 MeV and above

• Photon with at least 1.02 MeV (usuallymuch more) interacts with the electric field of an atomic nucleus, and explodesinto an electron and apositron (evil anti-electron in figure).The pair moves generally forward and splits the energy in excess of the1.02 MeV needed to create them (this is the resting energy of the positronand electron by $E^{¼}MC^2$)

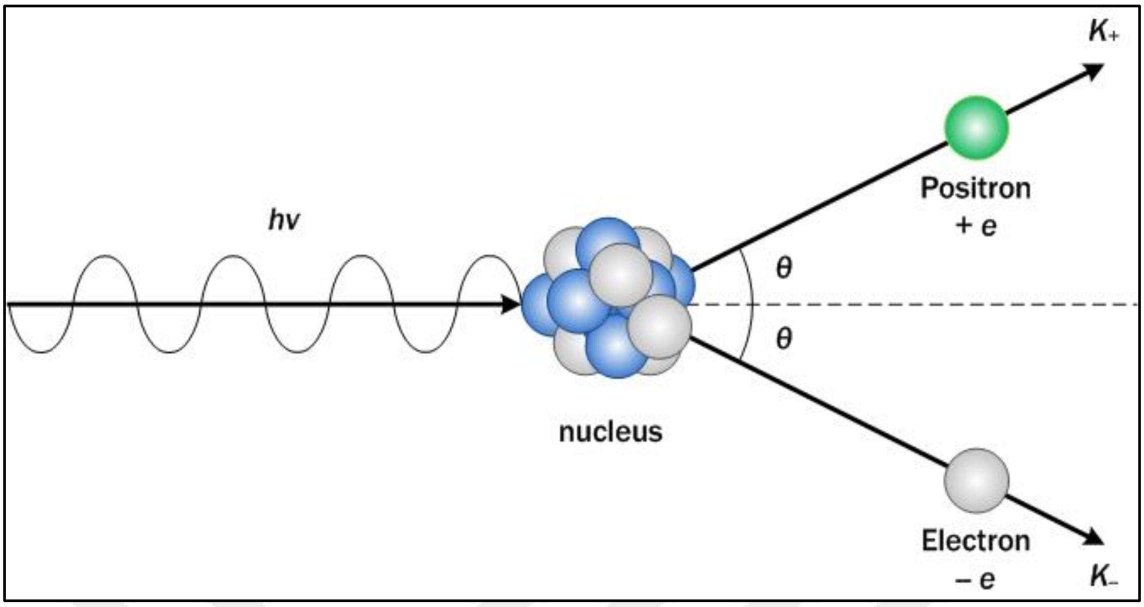


Figure.3.5. Pair production:

4. MATERIALS AND METHODS

In this research, the effective atomic numbers and the effective electron density of some biological tissue given in Table (4.1) were calculated using the WinXCom computer program at 1 keV to 100 GeV energy range

4.1. Theoretical Calculates

The photons which pass through matter are attenuated by absorption and scattering. Absorption-related attenuation follows the LambertBeer law,

$$I = I_0 e^{-\mu x} = I_0 e^{-(\mu / \rho)d} \tag{4.1}$$

Where I_0 and I are photon intensities that are un-attenuated and attenuated, d is the mass per unit area (g/cm^2) and the photon mass attenuation coefficient (cm^2/g). WinXCom code based on the mixture rule calculates the values of the mass attenuation coefficient (μ_ρ, cm^2 /g) for any component and complex materials at any energy between 1 keV and 100 GeV.

The mass attenuation coefficient of photon for any chemical compound or mixture of elements is given by ' mixture rule'

$$(\mu / \rho)_C = \sum w_i (\mu / \rho)_i \tag{4.2}$$

Where and (w_i) are the attenuation coefficient of weight fraction and photon mass of the ith constituent element, respectively. The fraction by weight (w_i) is given by, for a chemical compound

$$w_i = \frac{n_i A_i}{\sum n_j A_j} \tag{4.3}$$

WhereA_i is the atomic weight of the *i*th element and *Ni* is the number of formula units.

The total molecular cross-section (σ_m, barns/molecule) values are calculated from the following equation 4.4

$$\sigma_m = \frac{(\mu/\rho)_{c.}}{N_A} M \tag{4.4}$$

Where *M* is the molecular weight. The electronic cross-sections (σ_el, barn/electrons) are calculated as follows

$$\sigma_e = \frac{1}{N_A} \sum \frac{A_i}{Z_i} f_i \mu_i \tag{4.5}$$

Wheref_i and Z_i are the fractional abundance and atomic number of constituent element, respectively.

$$f_i = \frac{n_i}{\sum n_i} \tag{4.6}$$

The number of atoms in the constituent element is where n_i is. You may write an effective atomic number as the ratio between the atomic and electronic cross-sections. The effective atomic number (Z_{eff}) can be derived as follows for total photon interaction; Z_{eff} can also be calculated from Eq.9.

$$Z_{eff} = \frac{\sigma_a}{\sigma_b} \tag{4.7}$$

$$Z_{eff} = \frac{\sum_i f_i A_i \mu_i}{\sum_j f_j \frac{A_j}{Z_j} \mu_j} \tag{4.8}$$

Where $\mu_i$is the total attenuation coefficient, in equation (8), the (Z_{eff}) change can be derived using the attenuation coefficients of photoelectric effect, incoherent scatteringand pair production instead of total μ_i. Therefore, the impact of the three factors can be seen separately on (Z_{eff})'s change The electron density, N_{ell} (the number of electrons per unit mass, electron / g) can be determined as follows;

$$N_{el} = N_A \frac{Z_{eff}}{\langle A \rangle} \tag{4.9}$$

Where $\langle A \rangle$ is the average atomic mass of the compound.

4.2. Biological Tissues

In the study there was some biological tissue and density reported in Table 4.1 by Kramer (2006).

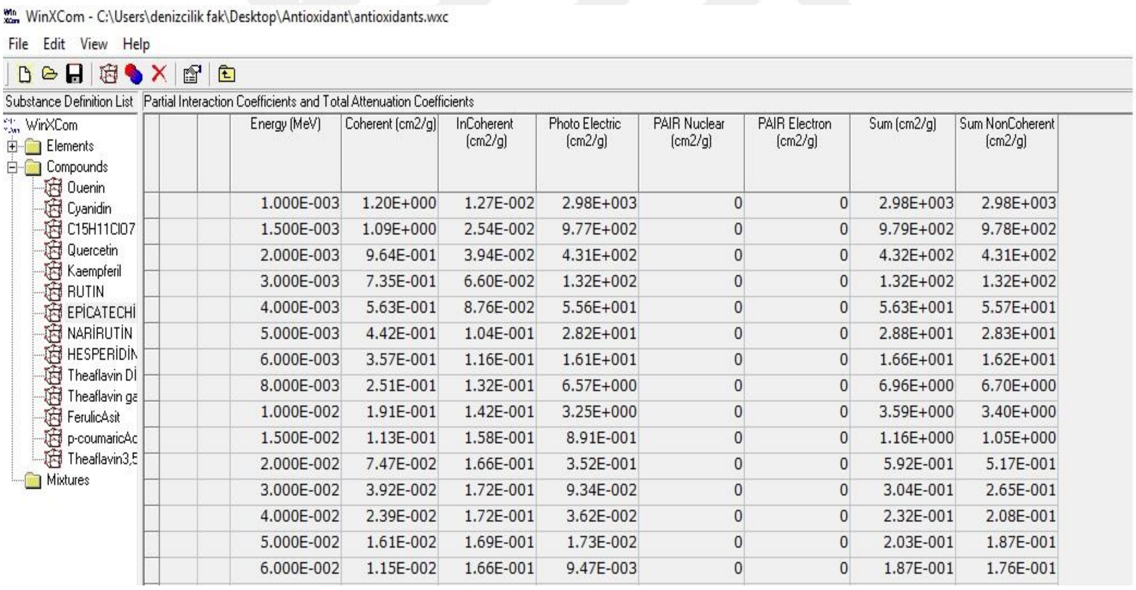
Table 4.1 Biological tissues

Composition of elemental tissue Used in computer software WinXCom.

Atom	Soft Tissue (%)	Muscle Tissue (%)	Adipose Tissue (%)	Skin Tissue (%)	Lungs Tissue (%)	Skeleton Cartilage (%)	Skeleton Cortical (%)
H	10.4	10.2	11.4	10.0	10.3	9.6	3.4
C	12.4	14.3	59.8	20.4	10.5	9.9	15.5
N	2.6	3.4	0.7	4.2	3.1	2.2	4.2
O	73.5	71.0	27.8	64.5	74.9	74.4	43.5
Na	0.2	0.1	0.1	0.2	0.2	0.5	0.1
Mg							0.2
P	0.2	0.2		0.1	0.2	2.2	10.3
S	0.2	0.3	0.1	0.2	0.3	0.9	
Cl	0.2	0.1	0.1	0.3	0.3	0.3	
K	0.2	0.4		0.1	0.2		
Ca	0.02						22.5
Fe	0.02						
ρ (g cm−3)	1.05	10.5	0.95	1.09	0.26	1.1	1.92

4.3. WinXCom Program

A program called XCom. were developed by Berger and Hubbell (1987/99) to calculate cross-sections interaction of partial photon such as the mass attinuation coefficients, atomic photoelectric effect, incoherent scattering, coherent scattering and pair production of any element, compound and weight percent of the known mixture such at 1 keV-100 GeV energy range.
Later, XCom program was developed by Gerward et al. (2001, 2004) and developed a version of Windows called WinXCom. It is able to transfer the data of defined and recorded material in a WinXCom program to a Microsoft Excel environment. Therefore, it makes easier for the calculations and graphic drawings to be made later. In this study, the mass reduction coefficients for 7 biological tissues were obtained theoretically with the help of WinXCom program.



Energy (MeV)	Coherent (cm2/g)	InCoherent (cm2/g)	Photo Electric (cm2/g)	PAIR Nuclear (cm2/g)	PAIR Electron (cm2/g)	Sum (cm2/g)	Sum NonCoherent (cm2/g)
1.000E-003	1.20E+000	1.27E-002	2.98E+003	0	0	2.98E+003	2.98E+003
1.500E-003	1.09E+000	2.54E-002	9.77E+002	0	0	9.79E+002	9.78E+002
2.000E-003	9.64E-001	3.94E-002	4.31E+002	0	0	4.32E+002	4.31E+002
3.000E-003	7.35E-001	6.60E-002	1.32E+002	0	0	1.32E+002	1.32E+002
4.000E-003	5.63E-001	8.76E-002	5.56E+001	0	0	5.63E+001	5.57E+001
5.000E-003	4.42E-001	1.04E-001	2.82E+001	0	0	2.88E+001	2.83E+001
6.000E-003	3.57E-001	1.16E-001	1.61E+001	0	0	1.66E+001	1.62E+001
8.000E-003	2.51E-001	1.32E-001	6.57E+000	0	0	6.96E+000	6.70E+000
1.000E-002	1.91E-001	1.42E-001	3.25E+000	0	0	3.59E+000	3.40E+000
1.500E-002	1.13E-001	1.58E-001	8.91E-001	0	0	1.16E+000	1.05E+000
2.000E-002	7.47E-002	1.66E-001	3.52E-001	0	0	5.92E-001	5.17E-001
3.000E-002	3.92E-002	1.72E-001	9.34E-002	0	0	3.04E-001	2.65E-001
4.000E-002	2.39E-002	1.72E-001	3.62E-002	0	0	2.32E-001	2.08E-001
5.000E-002	1.61E-002	1.69E-001	1.73E-002	0	0	2.03E-001	1.87E-001
6.000E-002	1.15E-002	1.66E-001	9.47E-003	0	0	1.87E-001	1.76E-001

Figure 4.1 WinXComcomputer program.

To create a compound in the program by clicking on the compound definition form, the elements on the screen and enter the number of atoms in the compound is enough.

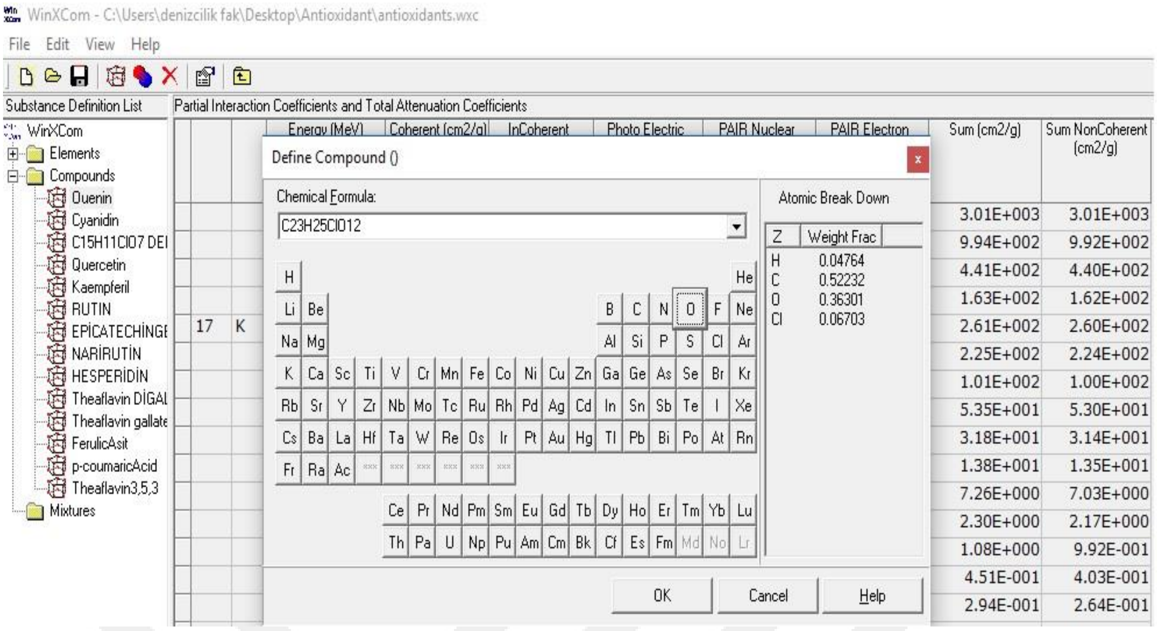


Figure 4.2 WinXComcompounding with computer program.

After obtaining the data of mass atteniation coefficients for some biological tissue from WinXCom computer program, all parameters were calculated using equations (4.10) - (4.11).

4.4. Experimental Measuremetnts

The mass attenuation coefficients of a patient's lung and skeletal structure were calculated using at Lambert's law(4.1) datas obtained from first tomography image of her patient was taken. Measurements were taken at 1 and 2MeV energy

$$I = I_0 e^{-\mu x} = I_0 e^{-(\mu/\rho)d}$$

Table 4.2 Experimental calculation.

Martial	Energy (MeV)	μ/ρ
Lung tissue	1 MeV	7.24×10^{-2}
Skeleton cartilage	2 MeV	4.29×10^{-2}

Table 4.3Theoretical calculation.

Martial	Energy (MeV)	μ/ρ
Lung tissue	1 MeV	7.03×10^{-2}
Skeleton cartilage	2 MeV	4.87×10^{-2}

In the experiment, we measured (I/I_o) and after we calculate of μ/ρ by using (I/I_o).

For the lung tissue, ln (I/I_o) is equal to 0.16296 and we got the Mass attenuation coefficient 7.24x10-2 compared by theoretical that 7.03x10-2 in WinXCom code, finally, we found not too much difference between both.

For the skeleton cartilage, ln (I/I_o) is equal to 0.28325 and we got the mass attenuation coefficient 4.29x10-2 in WinXCom code, finally, we found not too much difference between both.

5. RESULTS AND DISCUSSION

Mass attenuation coefficient with photon energy has been measured in the present work (adipose tissue, lung tissue, muscle tissue, skeleton cartilage, cortical skeleton, skin tissue, soft tissue). Subsequently, Z_{eff} was calculated from Equation (4.8) and N_{ell} was calculated from equation (4.9) using Gerward et al., (2004) from WinXCom.

To measure the Z_{eff} and N_{ell} for the (adipose tissue, lung tissue, muscle tissue, skeleton cartilage, cortical skeleton, skin tissue, soft tissue), the obtained values of μ_{ρ} are used. The combinations of μ_{ρ}, Z_{eff}, and N_{ell} with photon energy were analyzed in different proportions for biological compounds of various elements (Table5.1-5.3), the results are shown graphically in Figs. (5.1–5.3) mass attenuation coefficient, and total photon interaction processes have been analyzed in Table (5.4-5.17), the results are shown graphically in Figs. (5.4–5.17) for the complete interaction of photons (photoelectric effect, incoherent scattering and pair production), graphs display the energy range 1keV–100GeV. The present findings clearly support Hine's (1952) claim that the effective atomic number varies according to energy.

Table 5.1 Mass attenuation coefficient (cm^2/g) to WinXcom results.

Energy	Adiops tissue	lung tissue	soft tissue	skin tissue	skeleton cortical	skeleton cartilag	Muscle tissue
0.00104	2360.699	3425.120	3389.779	3216.049	3407.430	3407.806	2126.743
0.002	379.9530	574.6898	568.3135	536.2613	1294.445	576.6897	336.8933
0.005	25.87492	83.05675	80.94944	75.70337	129.6101	92.2086	49.87
0.01	3.26799	15.04259	24.35838	13.63858	73.6711	12.32034	9.03033
0.1	0.16884	0.2053	0.26862	0.20252	0.31483	0.18324	0.19604
1	0.07079	0.08882	0.10536	0.08857	0.08332	0.07747	0.08868
5	0.02995	0.03935	0.04905	0.03921	0.03745	0.03357	0.03911
10	0.02145	0.02407	0.02746	0.0239	0.02467	0.02292	0.0234
50	0.01507	0.01692	0.01714	0.01664	0.02048	0.01684	0.0155
100	0.01526	0.01659	0.01654	0.01626	0.0214	0.01713	0.0148
1000	0.01766	0.01949	0.01893	0.01903	0.02646	0.02021	0.01697
10000	0.0185	0.02077	0.02056	0.02029	0.02821	0.02129	0.01813
100000	0.01865	--	0.02088	0.02053	0.02852	0.02148	0.01836

Table5.2 Effective atomic numbers (Z_{eff}) to WinXCom code program for mass attenuation coefficient.

Energy	Adiops tissue	lung tissue	soft tissue	skin tissue	skeleton cortical	skeleton cartilag	Muscle tissue
0.00104	14.41083	7.83242	15.8	7.64846	9.57	7.89	7.65884
0.002	14.70207	7.85969	15.9	7.6877	9.76	7.91	7.68005
0.005	16.79731	8.18366	16.9	7.935	15.8	8.75	8.00026
0.01	16.81016	7.89307	16.9	7.62854	16.2	8.53	7.76554
0.1	11.97215	3.51102	14.7	3.50304	6.74	3.66	3.68012
1	10.73478	3.43747	14	3.43729	5.99	3.57	3.60589
5	11.31515	3.57209	14.4	3.56416	6.32	3.71	3.74106
10	12.15137	3.81996	14.9	3.79767	6.87	3.98	3.98791
50	14.06164	4.87168	15.9	4.78866	8.65	5.08	5.00693
100	14.42211	5.2369	16	5.13275	9.11	5.46	5.35037
1000	14.64881	5.54341	16.1	5.42207	9.44	5.77	5.63453
10000	14.63668	5.53287	16.1	5.41236	9.43	5.76	5.62478

100000	14.63217	5.52733	16.1	5.40717	9.42	5.75	5.61967

Table5.3 Electron density (N_{ell}) WinXCom code program for mass attenuation coefficient.

Energy	Adipose tissue	lung tissue	soft tissue	skin tissue	skeleton cortical	skeleton cartilag	Muscle tissue
0.00104	7.83E+23	4.24E+23	1.05E+24	4.14E+23	5.18E+23	2.49E+24	4.15E+23
0.002	7.99E+23	4.26E+23	1.05E+24	4.17E+23	5.29E+23	2.49E+24	4.16E+23
0.005	9.13E+23	4.43E+23	1.12E+24	4.30E+23	8.54E+23	2.76E+24	4.33E+23
0.01	9.13E+23	4.28E+23	1.12E+24	4.13E+23	8.75E+23	2.69E+24	4.21E+23
0.1	6.50E+23	1.90E+23	9.72E+23	1.90E+23	3.65E+23	1.15E+24	1.99E+23
1	5.83E+23	1.86E+23	9.23E+23	1.86E+23	3.25E+23	1.13E+24	1.95E+23
5	6.15E+23	1.94E+23	9.47E+23	1.93E+23	3.42E+23	1.17E+24	2.03E+23
10	6.60E+23	2.07E+23	9.80E+23	2.06E+23	3.72E+23	1.25E+24	2.16E+23
50	7.84E+23	2.84E+23	1.06E+24	2.78E+23	4.93E+23	1.72E+24	2.90E+23
100	7.96E+23	3.00E+23	1.07E+24	2.94E+23	5.11E+23	1.82E+24	3.05E+23
1000	7.95E+23	3.00E+23	1.06E+24	2.93E+23	5.11E+23	1.82E+24	3.05E+23
10000	7.95E+23	3.00E+23	1.06E+24	2.93E+23	5.10E+23	1.81E+24	3.05E+23

The variation of Z_{eff} and N_{ell}'s with of photon energy for total photon interaction (Fig.5.2-5.3) demonstrates the predominance of various interaction processes in different energy regions. All biological substances are almost similar in behavior.

Show results against photon energy from total mass attenuation coefficients of selected biological compounds.From the figure, it can be seen that the variability in $\mu_\rho$with biological compounds is high below 100 keV and insignificant between 0.1 and 10MeV and further the important variation in μ_ρ beyond 50MeV of photon energy.Attenuation processes dominate for the three energy ranges, photoelectric effect, incoherent scattering, and pair production respectively.

Table5.4 Effective atomic numbers (Z_{eff})for the adipose tissue to WinXComcode programforphotoelectric, incoherent scattering and pair production.

Energy	Z_{eff} photoelectric	Z_{eff} incoherent	Z_{eff} pair production
0.00104	15.99686	14.81479	-
0.002	16.12154	14.8079	-
0.005	16.933	14.89193	-
0.01	16.94855	15.09426	-
0.1	16.97006	15.49317	-
1	16.97454	15.53295	15.53413
5	16.97351	15.53358	15.53279
10	16.97296	15.53401	15.51615
50	16.97243	15.53405	15.49862
100	16.97236	15.53395	15.42346
1000	16.97229	15.53406	15.39459
10000	16.97228	15.53417	15.38927
100000	16.97228	15.53418	15.38941

Table 5.5 Effective atomic numbers (Z_{eff})for the lung tissue to WinXCom code program for photoelectric, incoherent scattering and pair production.

Energy	Z_{eff} photoelectric	Z_{eff} incoherent	Z_{eff} pair production
0.00104	7.92016	6.12728	--
0.002	7.95167	6.25259	--
0.005	8.72873	6.64592	--
0.01	8.91331	6.87103	--
0.1	9.40166	7.12044	--
1	9.58687	7.13272	7.13273
5	9.53472	7.1328	7.13255
10	9.51135	7.13291	7.12559
50	9.48912	7.13265	7.11457
100	9.48616	7.13289	7.05161
1000	9.48338	7.133	7.0236
10000	9.4831	7.13265	7.01831
100000	9.48309	7.13288	7.01831

Table 5.6 Effective atomic numbers (Z_{eff})for the muscle tissue toWinXComcode programfor photoelectric, incoherent scattering and pair production.

Energy	Z_{eff} photoelectric	Z_{eff} incoherent	Z_{eff} pair production
0.00104	7.74595	6.16271	--
0.002	7.76903	6.27183	--
0.005	8.54731	6.6238	--
0.01	8.74428	6.82298	--
0.1	9.27567	7.04097	--
1	9.4817	7.05192	7.05221
5	9.42316	7.05199	7.0519
10	9.39715	7.0521	7.04758
50	9.37258	7.05186	7.03978
100	9.36908	7.05208	6.98556
1000	9.36607	7.05218	6.95764
10000	9.36581	7.05186	6.95201
100000	6.95188	7.05207	6.95188

Table 5.7 Effective atomic numbers (Z_{eff})for the skeleton cartilag to WinXCom code programfor photoelectric, incoherent scattering and pair production.

Energy	Z_{eff} photoelectric	Z_{eff} incoherent	Z_{eff} pair production
0.00104	8.0144	6.40372	--
0.002	8.03623	6.50337	--
0.005	9.60837	6.84966	--
0.01	9.86817	7.07253	--
0.1	10.48161	7.34525	--
1	10.68714	7.36057	--
5	10.63109	7.36077	7.36102
10	10.60516	7.36087	7.3606
50	10.58066	7.36063	7.35447
100	10.5774	7.36093	7.34432
1000	10.574	7.36095	7.27893
10000	10.57381	7.3607	7.24709
100000	10.57371	7.36091	7.24074

Table 5.8 Effective atomic numbers (Z_{eff})for the skeleton cortical to WinXCom code programfor photoelectric, incoherent scattering and pair production.

Energy	Z_{eff} photoelectric	Z_{eff} incoherent	Z_{eff} pair production
0.00104	11.65269	11.26374	--
0.002	11.90363	10.32152	--
0.005	17.57835	9.92333	--
0.01	17.94367	10.15412	--
0.1	18.52909	10.77715	--
1	18.67758	10.85855	--
5	18.63775	10.86065	7.36102
10	18.61977	10.86104	7.3606
50	18.60238	10.86128	7.35447
100	18.60001	10.86124	7.34432
1000	18.59782	10.86099	7.27893
10000	18.59752	10.86176	7.24709
100000	18.59759	10.862	7.24074

Table 5.9 Effective atomic numbers (Z_{eff})for theskin tissue to WinXCom code program for photoelectric, incoherent scattering and pair production.

Energy	Zeff photo electric	Zeff incoherent	Zeff pair production
0.00104	7.76E+00	5.97E+00	--
0.002	7.80E+00	6.09E+00	--
0.005	8.42006	6.46014	--
0.01	8.5749	6.67261	--
0.1	8.98493	6.90495	--
1	9.14027	6.91633	--
5	9.09728	6.91636	6.91661
10	9.07757	6.91649	6.9163
50	9.05889	6.91623	6.9118
100	9.05645	6.91645	6.90351
1000	9.0541	6.91657	6.84492
10000	9.05382	6.9162	6.81444
100000	9.05383	6.91645	6.80827

Table 5.10 Effective atomic numbers (Z_{eff})for the soft tissue to WinXCom code program for photoelectric, incoherent scattering and pair production.

Energy	Z_{eff} photoelectric	Z_{eff} incoherent	Z_{eff} pair production
0.00104	--	16.37119	--
0.002	--	16.34695	--
0.005	--	16.33107	--
0.01	--	16.37959	--
0.1	--	16.51484	--
1	--	16.52724	--
5	16.52761	16.52756	16.52772
10	16.52709	16.52759	16.52723
50	16.52073	16.52768	16.52221
100	16.51429	16.52767	16.51658
1000	16.49202	16.52767	16.49351
10000	16.48528	16.52782	16.48568
100000	16.48433	16.52773	16.48434

Table 5.11 Electron density (N_{ell}) for the adipose tissue to WinXComcode program for photoelectric, incoherent scattering and pair production.

Energy	N_{ell} photoelectric	N_{ell} incoherent	N_{ell} pair production
0.00104	8.69E+23	8.05E+23	--
0.002	8.73E+23	8.05E+23	--
0.005	9.20E+23	8.09E+23	--
0.1	9.22E+23	8.42E+23	--
1	9.22E+23	8.44E+23	8.44E+23
5	9.22E+23	8.44E+23	8.44E+23
10	9.22E+23	8.44E+23	8.43E+23
50	9.22E+23	8.44E+23	8.42E+23
100	9.22E+23	8.44E+23	8.38E+23
1000	9.22E+23	8.44E+23	8.36E+23
10000	9.22E+23	8.44E+23	8.36E+23
100000	9.22E+23	8.44E+23	8.36E+23

Table 5.12 Electron density (N_{ell}) for the lung tissue to WinXComcode program for photoelectric, incoherent scattering and pair production.

Energy	N_{ell} photoelectric	N_{ell} incoherent	N_{ell} pair production
0.00104	4.29E+23	3.32E+23	--
0.002	4.31E+23	3.39E+23	--
0.005	4.73E+23	3.60E+23	--
0.01	4.83E+23	3.72E+23	--
0.1	5.09E+23	3.86E+23	--
1	5.19E+23	3.86E+23	3.87E+23
5	5.17E+23	3.86E+23	3.86E+23
10	5.15E+23	3.86E+23	3.86E+23
50	5.14E+23	3.86E+23	3.86E+23
100	5.14E+23	3.86E+23	3.82E+23
1000	5.14E+23	3.87E+23	3.81E+23
10000	5.14E+23	3.86E+23	3.80E+23
100000	5.14E+23	3.86E+23	3.80E+23

Table 5.13 Electron density (N_{ell}) for the muscle tissue to WinXCom code program for photoelectric, incoherent scattering and pair production.

Energy	N_{ell} photoelectric	N_{ell} incoherent	N_{ell} pair production
0.00104	4.20E+23	3.34E+23	--
0.002	4.21E+23	3.40E+23	--
0.005	4.63E+23	3.59E+23	--
0.01	4.74E+23	3.70E+23	--
0.1	5.03E+23	3.82E+23	--
1	5.14E+23	3.82E+23	--
5	5.11E+23	3.82E+23	3.82E+23
10	5.09E+23	3.82E+23	3.82E+23
50	5.08E+23	3.82E+23	3.82E+23
100	5.08E+23	3.82E+23	3.81E+23
1000	5.08E+23	3.82E+23	3.79E+23
10000	5.07E+23	3.82E+23	3.77E+23
100000	5.07E+23	3.82E+23	3.77E+23

Table 5.14 Electron density (N_{ell}) for the skeleton cartilag to WinXCom code programphotoelectric, incoherent scattering and pair production.

Energy	N_{ell} photoelectric	N_{ell} incoherent	N_{ell} pair production
0.00104	2.53E+24	2.02E+24	--
0.002	2.53E+24	2.05E+24	--
0.005	3.03E+24	2.16E+24	--
0.01	3.11E+24	2.23E+24	--
0.1	3.31E+24	2.32E+24	--
1	3.37E+24	2.32E+24	--
5	3.35E+24	2.32E+24	2.32E+24
10	3.34E+24	2.32E+24	2.32E+24
50	3.34E+24	2.32E+24	2.32E+24
100	3.34E+24	2.32E+24	2.32E+24
1000	3.33E+24	2.32E+24	2.30E+24
10000	3.33E+24	2.32E+24	2.29E+24
100000	3.33E+24	2.32E+24	2.28E+24

Table 5.15 Electron density (N_{ell}) for the skeleton cortical to WinXCom code programphotoelectric, incoherent scattering and pair production.

Energy	N_{ell} photoelectric	N_{ell} incoherent	N_{ell} pair production
0.00104	6.31E+23	6.10E+23	--
0.002	6.45E+23	5.59E+23	--
0.005	9.52E+23	5.38E+23	--
0.01	9.72E+23	5.50E+23	--
0.1	1.00E+24	5.84E+23	--
1	1.01E+24	5.88E+23	--
10	1.01E+24	5.88E+23	5.88E+23
50	1.01E+24	5.88E+23	5.86E+23
100	1.01E+24	5.88E+23	5.85E+23
1000	1.01E+24	5.88E+23	5.78E+23
10000	1.01E+24	5.88E+23	5.76E+23
100000	1.01E+24	5.88E+23	5.76E+23

Table 5.16 Electron density (N_{ell}) for the skin tissue to WinXComcode program for photoelectric, incoherent scattering and pair production.

Energy	N_{ell} photoelectric	N_{ell} incoherent	N_{ell} pair production
0.00104	4.20E+23	3.24E+23	--
0.002	4.23E+23	3.30E+23	--
0.005	4.56E+23	3.50E+23	--
0.01	4.65E+23	3.62E+23	--
0.1	4.87E+23	3.74E+23	--
1	4.95E+23	3.75E+23	--
5	4.93E+23	3.75E+23	3.75E+23
10	4.92E+23	3.75E+23	3.75E+23
50	4.91E+23	3.75E+23	3.75E+23
100	4.91E+23	3.75E+23	3.74E+23
1000	4.91E+23	3.75E+23	3.71E+23
10000	4.91E+23	3.75E+23	3.69E+23
100000	4.91E+23	3.75E+23	3.69E+23

Table 5.17 Electron density (N_{ell}) for the soft tissue to WinXComcode program for photoelectric, incoherent scattering and pair production.

Energy	N_{ell} photoelectric	N_{ell} incoherent	N_{ell} pair production
0.00104	--	1.08E+24	--
0.002	--	1.08E+24	--
0.005	--	1.08E+24	--
0.01	--	3.62E+23	--
0.1	--	1.09E+24	--
1	--	1.10E+24	--
5	1.10E+24	1.10E+24	1.09E+24
10	1.10E+24	1.10E+24	1.09E+24
50	1.09E+24	1.10E+24	1.09E+24
100	1.09E+24	1.10E+24	1.09E+24
1000	1.09E+24	1.10E+24	1.09E+24
10000	1.09E+24	1.10E+24	1.09E+24
100000	1.09E+24	1.10E+24	1.09E+24

In the present the results are similar to the observations of Zavel'skii (1964) who proposed a direct relation of μ_ρ with low energy; this coefficient is not constant but depends on the incident photon energy. The coefficient is not constant but depends on the photon energy incident. The mass attenuation coefficient is found to be constant at the intermediate energy position, where incoherent scattering is the most dominant operation and is due to the linear Z-dependence of incoherent scattering and the insignificant role played by pair production thehigh energy region, the significant variance of the mass attenuation coefficient is due to the Z^2-dependence of pair production.

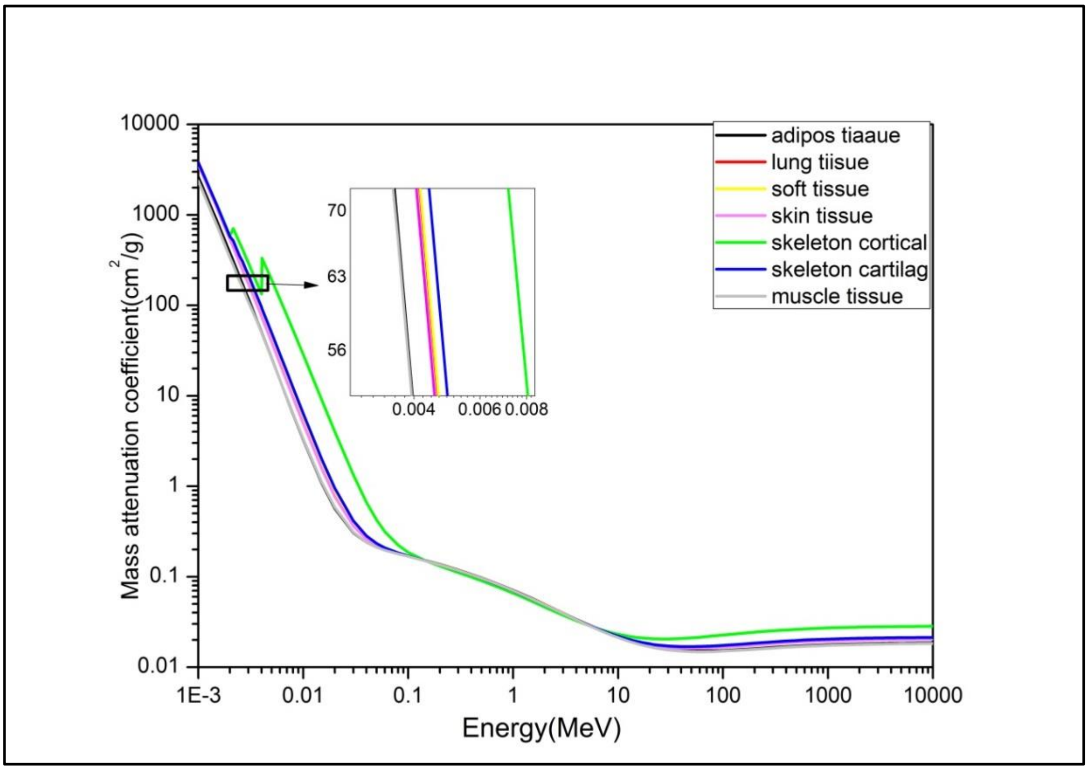


Figure 5.1 Variation of the total mass attenuation coefficient (cm^2/g) versus photon energy occurring for some biological tissue at an energy range (0.001MeV–10000MeV).

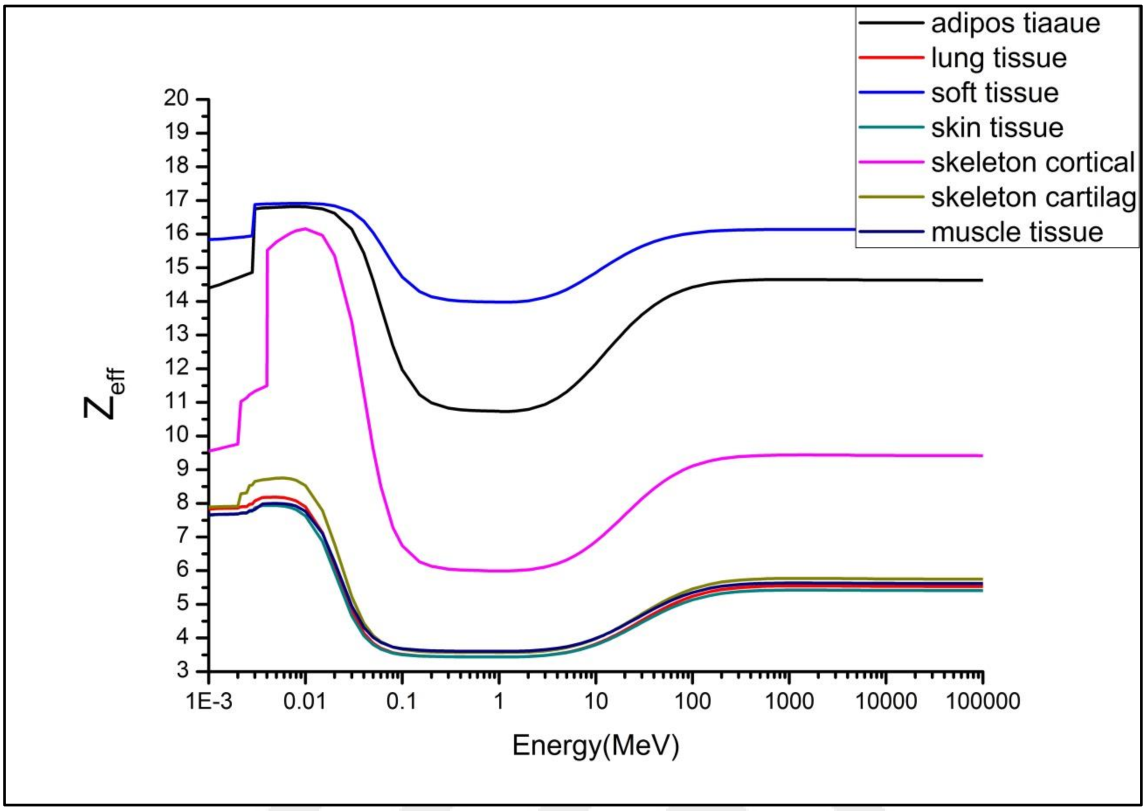


Figure 5.2 Effective atomic numbers (Z_{eff}) versus energy (MeV).

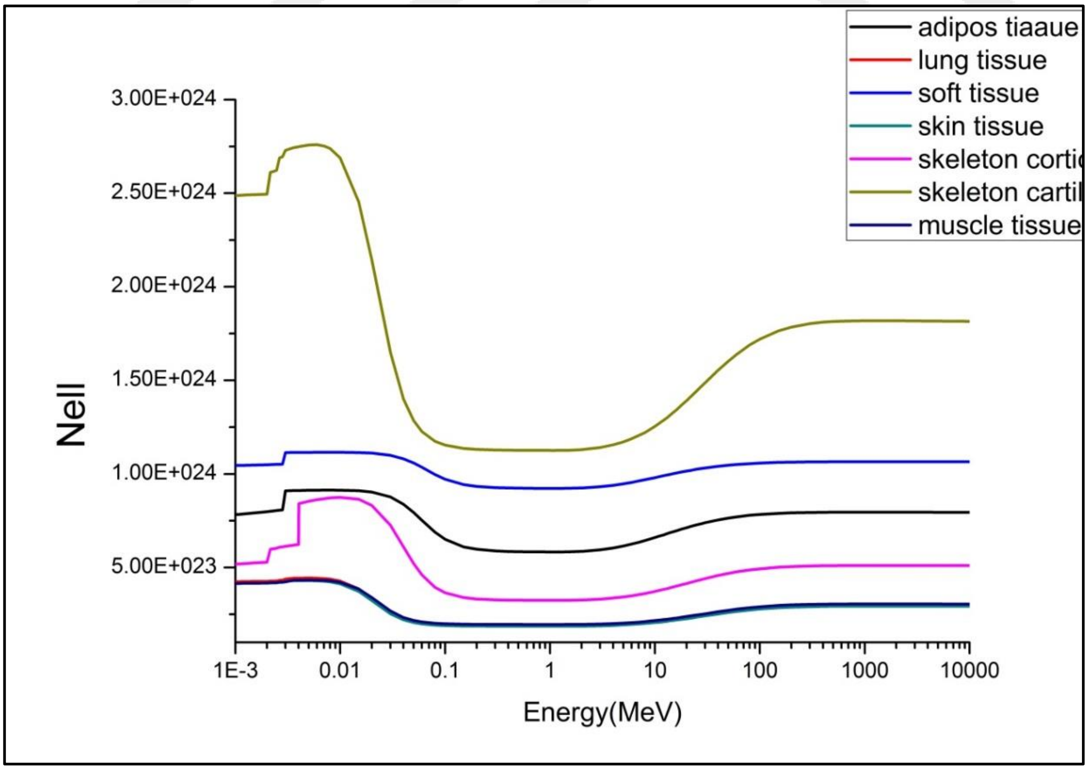


Figure 5.3 Electrondensity (Nell) versus energy (MeV).

Photoelectric interaction is shown in the figures (5.4-5.17), dependent Probability of interaction is proportional to Z^3/E^3, in the energy range (0.1MeV-10MeV), incoherent scattering becomes the dominant mechanism,The partial mass attenuation coefficient gradually decreases with the increase in incident photon energy-dependent probability proportional to (Z) atomic number, and in the photon energy range (10MeV-10000MeV) pair production in this component mass attenuation coefficient is constantly seen since pair production is independent of photon energy and proportional to the square atomic number Z^2 of the scattering.

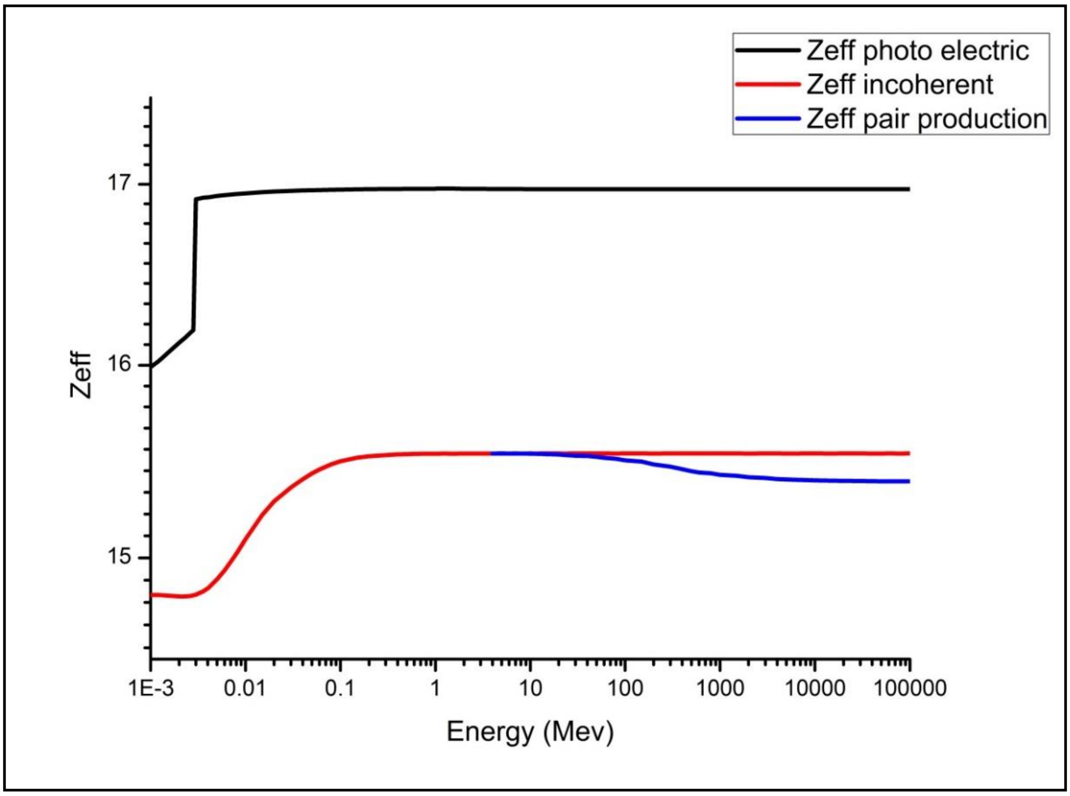


Figure 5.4Effective atomic numbers (Z_{eff}) of adipose tissue versus energy (MeV).

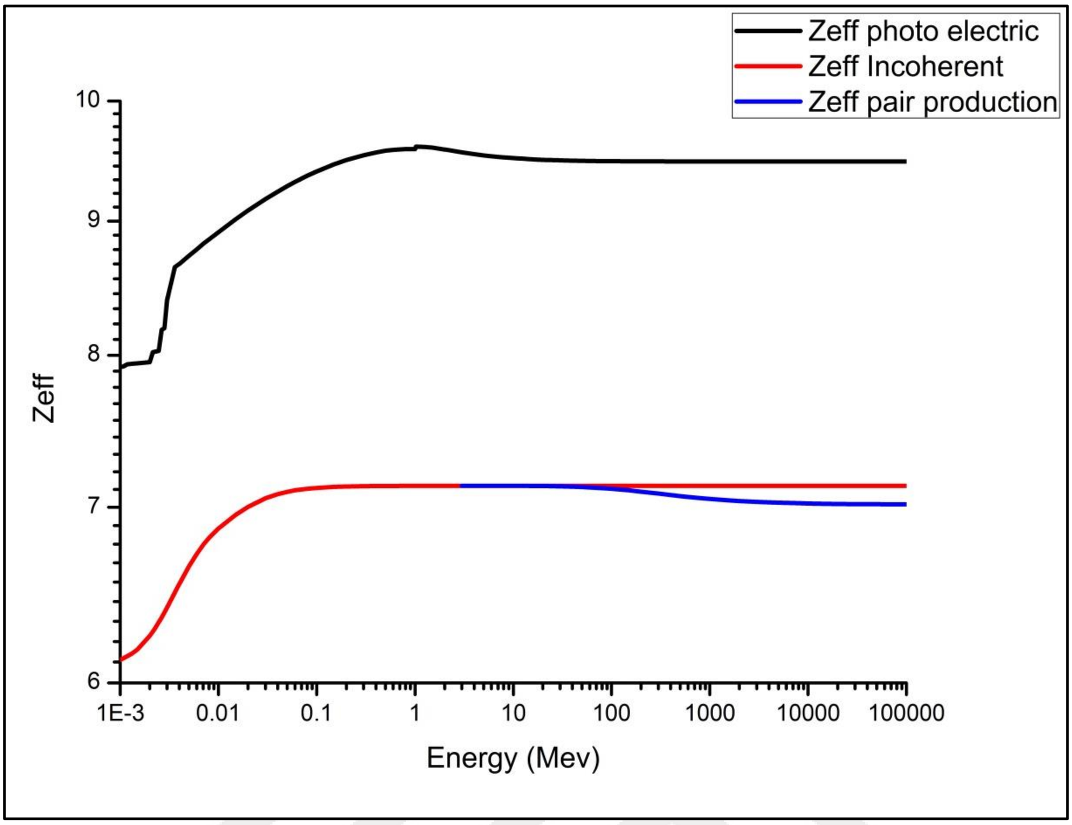


Figure 5.5 Effective atomic numbers (Z_{eff})of lung tissue versus energy (MeV).

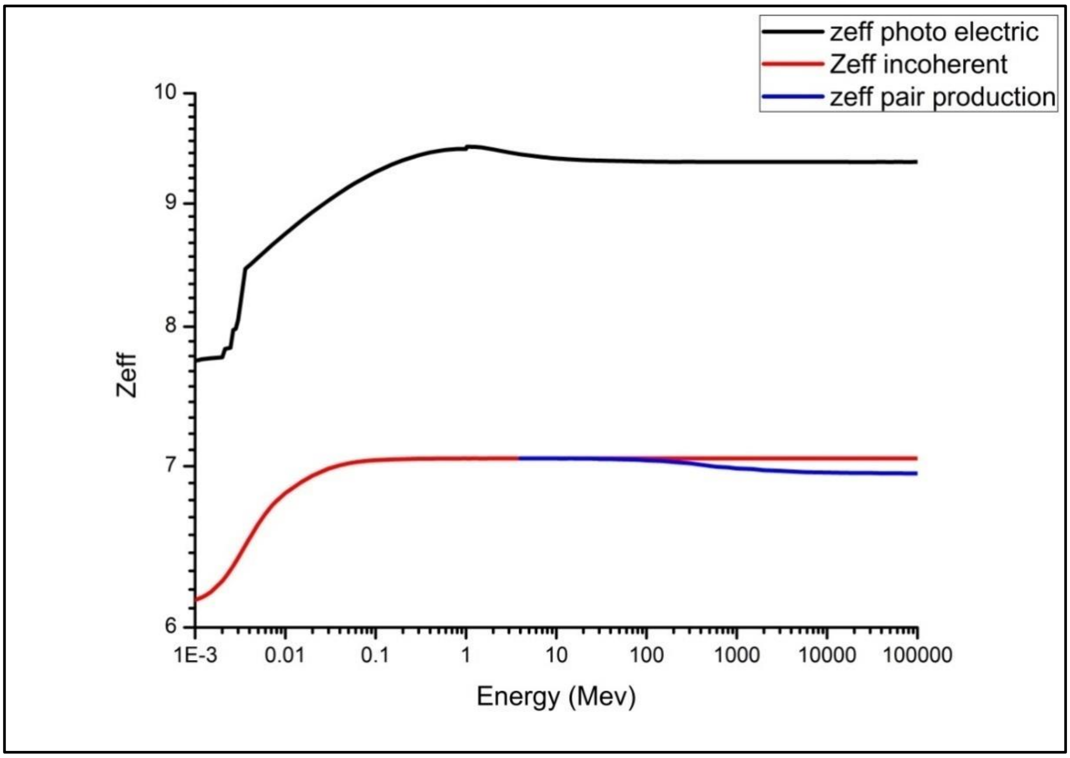


Figure 5.6 Effective atomic numbers (Z_{eff}) of muscle tissue versus energy (MeV).

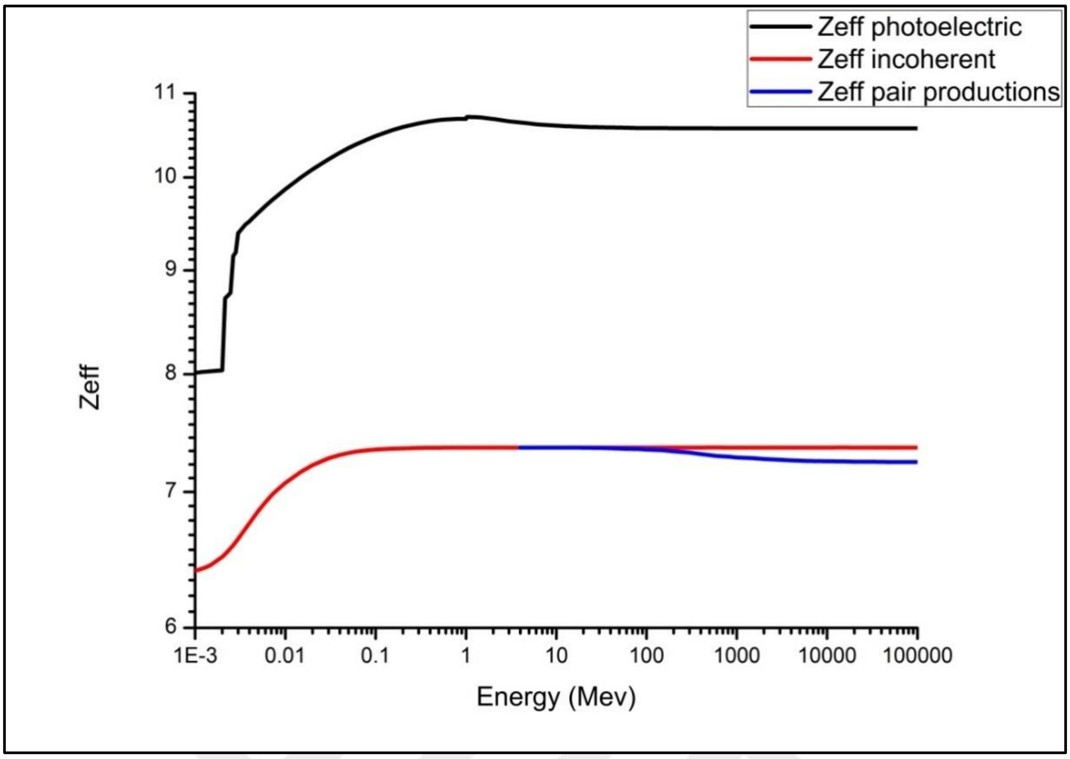


Figure 5.7 Effective atomic numbers (Z_{eff}) of skeleton cartilag versus energy (MeV).

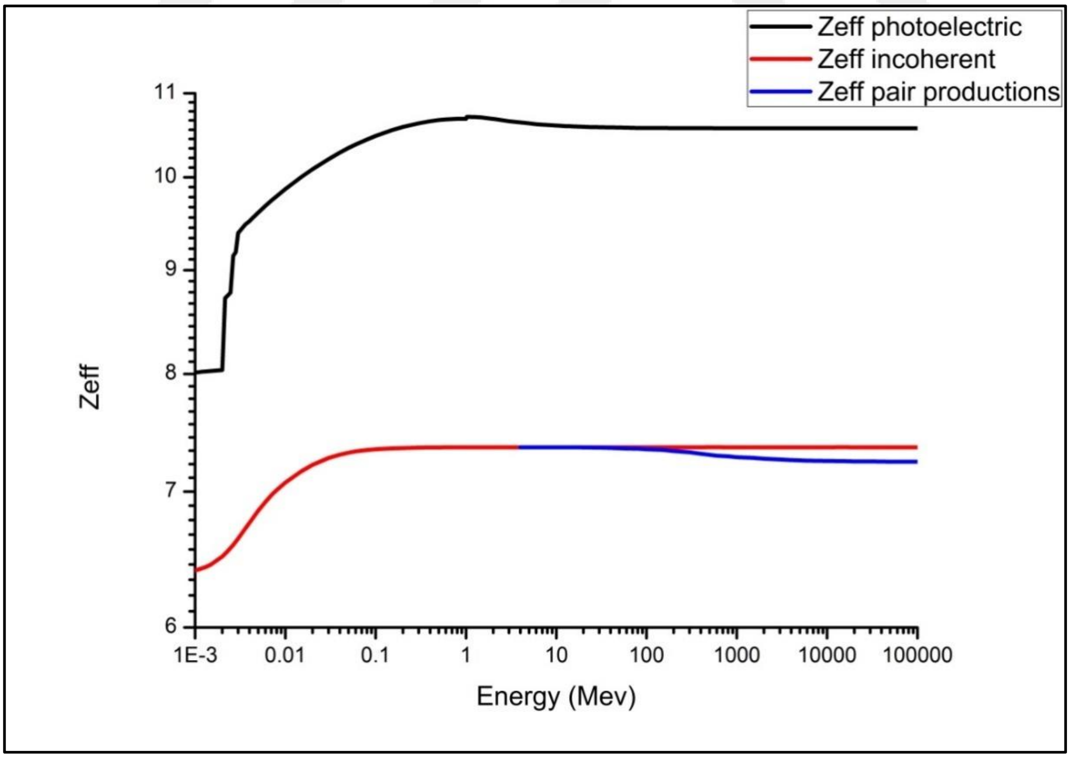


Figure 5.8 Effective atomic numbers (Z_{eff}) of skeleton cortical versus energy (MeV).

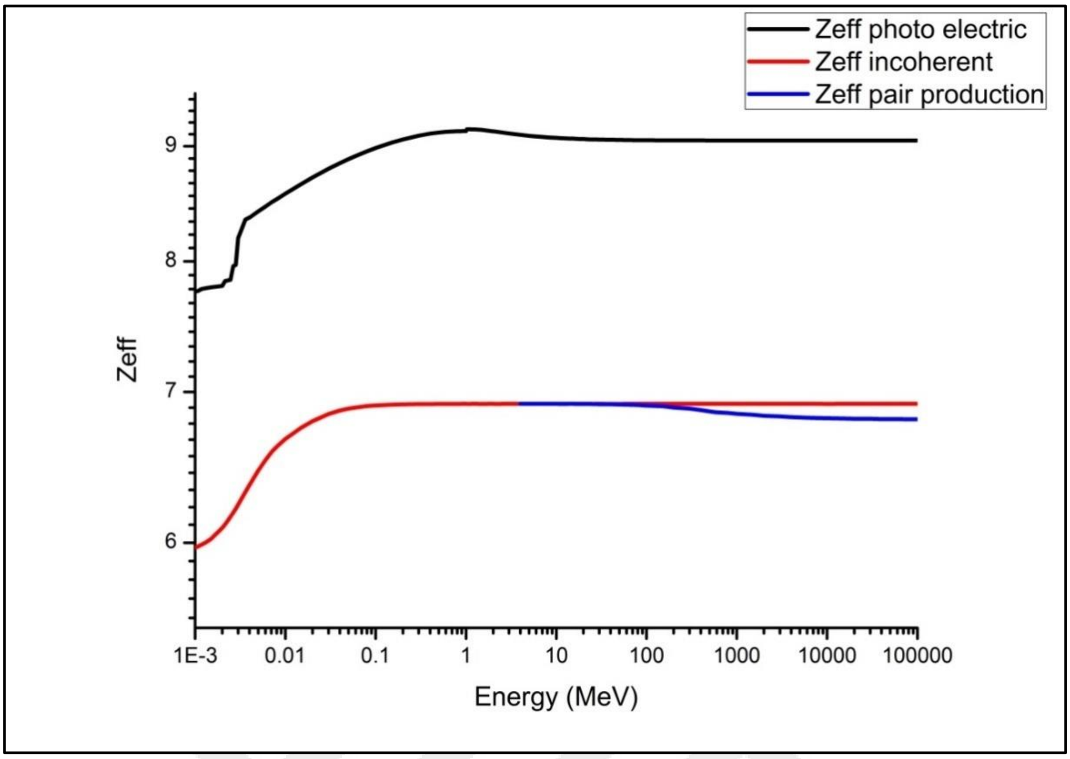


Figure 5.9 Effective atomic numbers (Z_{eff}) of skin tissue versus energy (MeV).

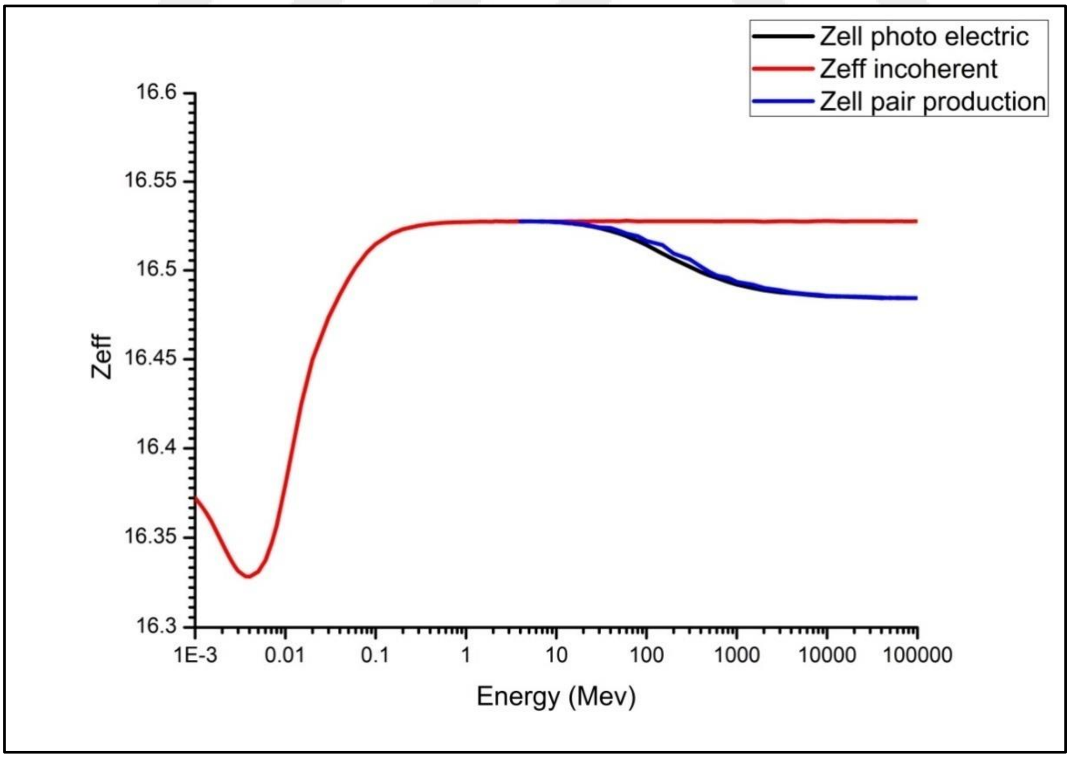


Figure 5.10 Effective atomic numbers (Z_{eff}) of soft tissueversus energy (MeV).

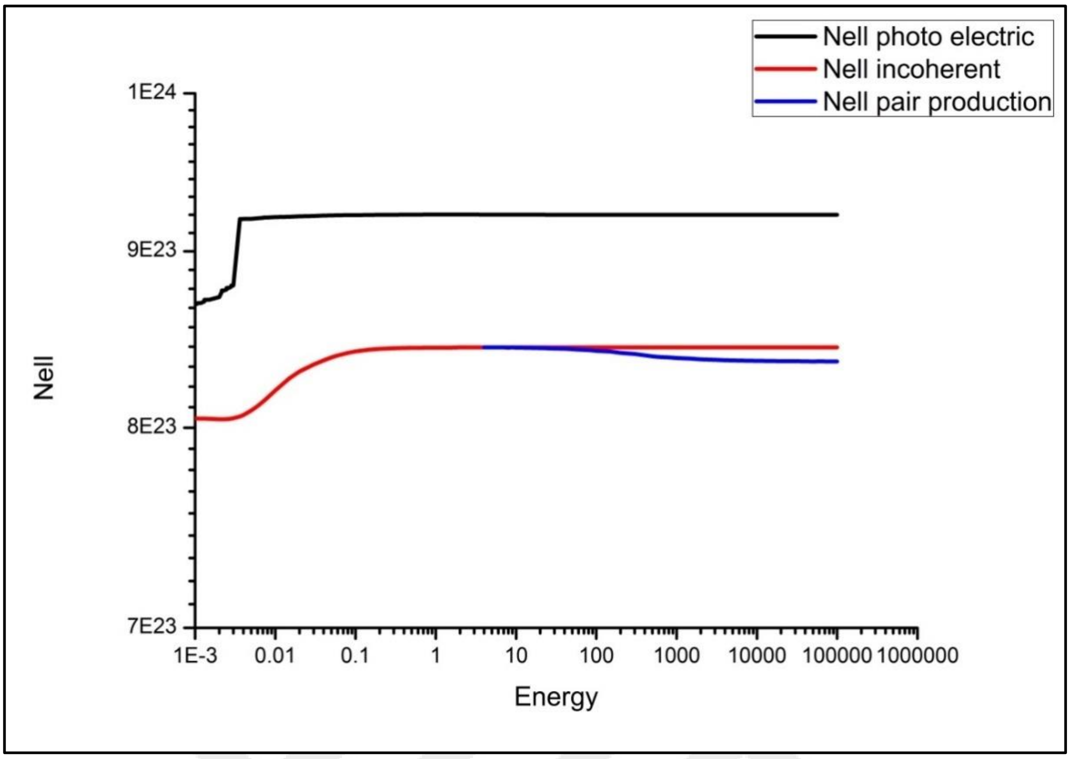


Figure 5.11 Electron density (N_{ell}) of adiposeversus energy (MeV).

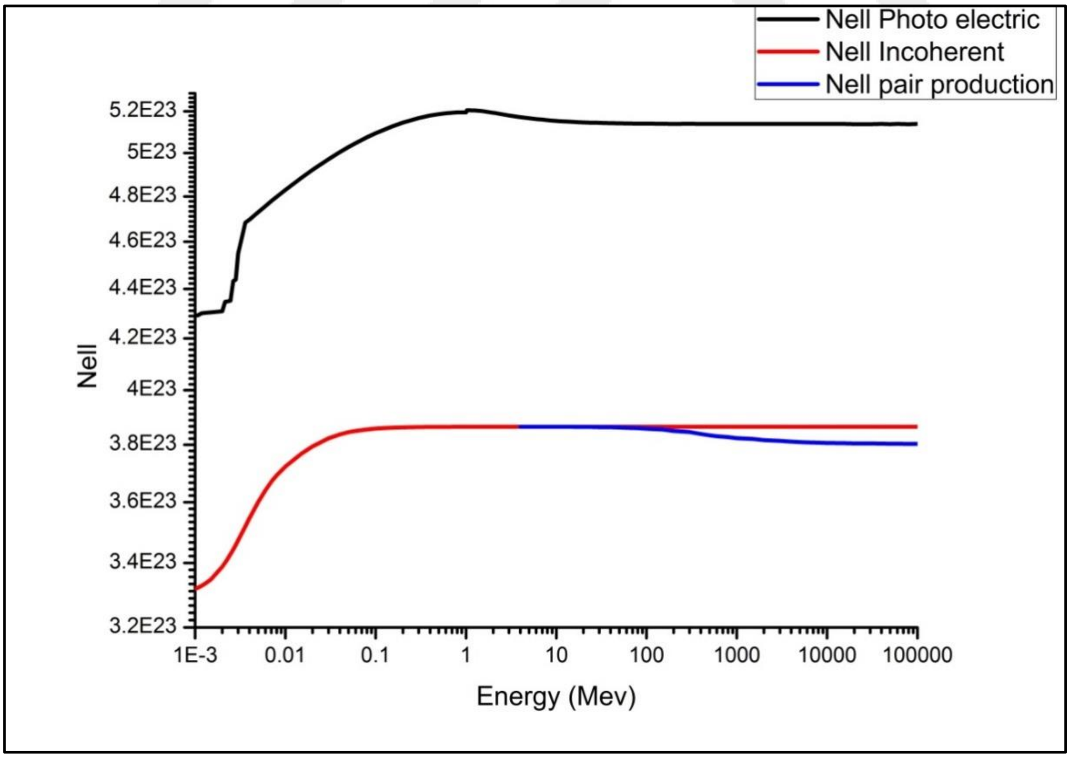


Figure 5.12 Electron density (N_{ell}) of lung tissue versus energy (MeV).

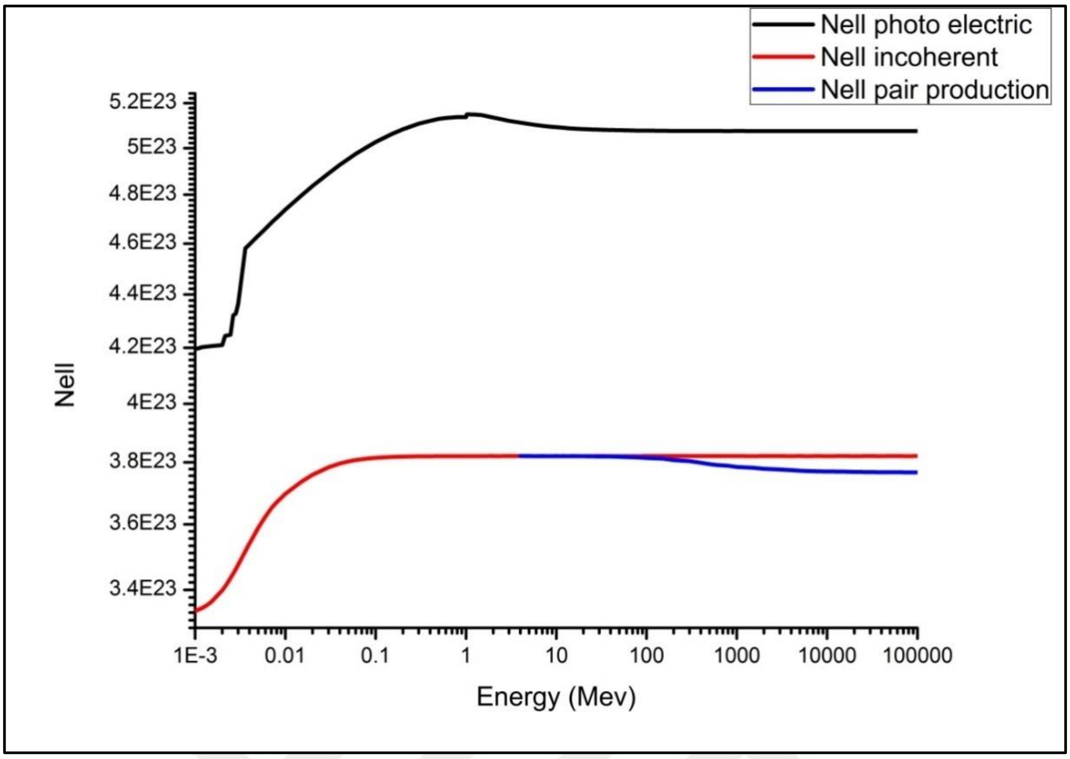


Figure 5.13 Electron density (N_{ell}) of muscle tissue versus energy (MeV).

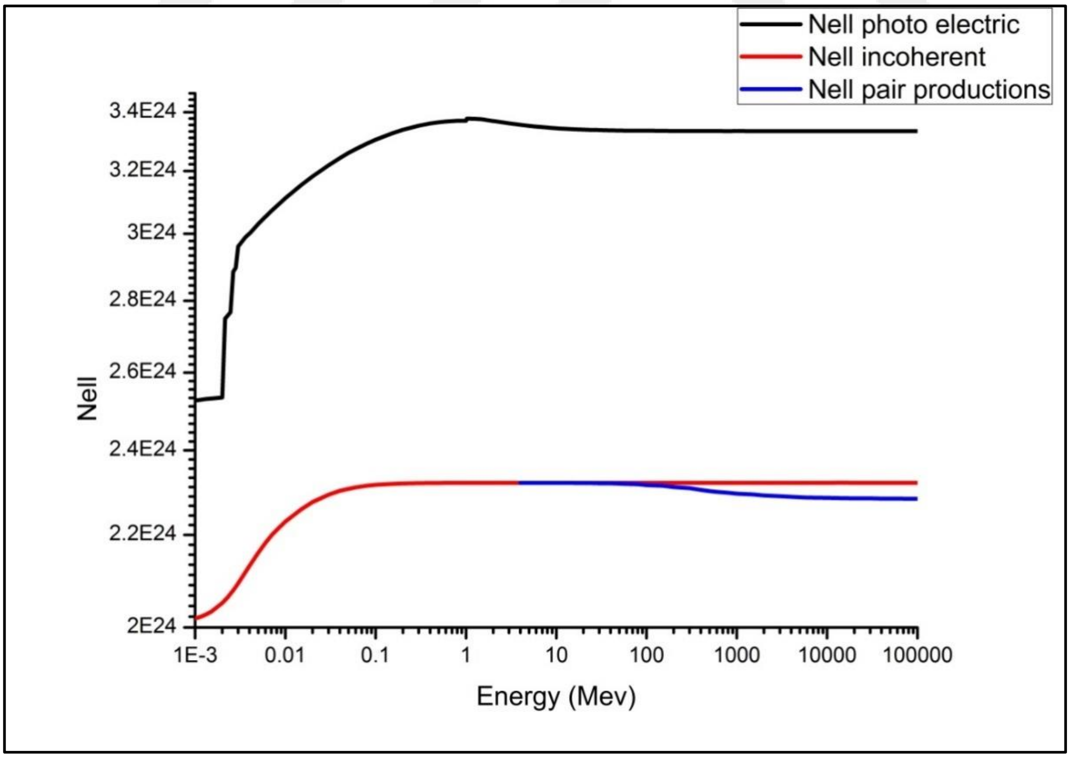


Figure 5.14 Electron density (N_{ell}) of skeleton cartilagversus energy (MeV).

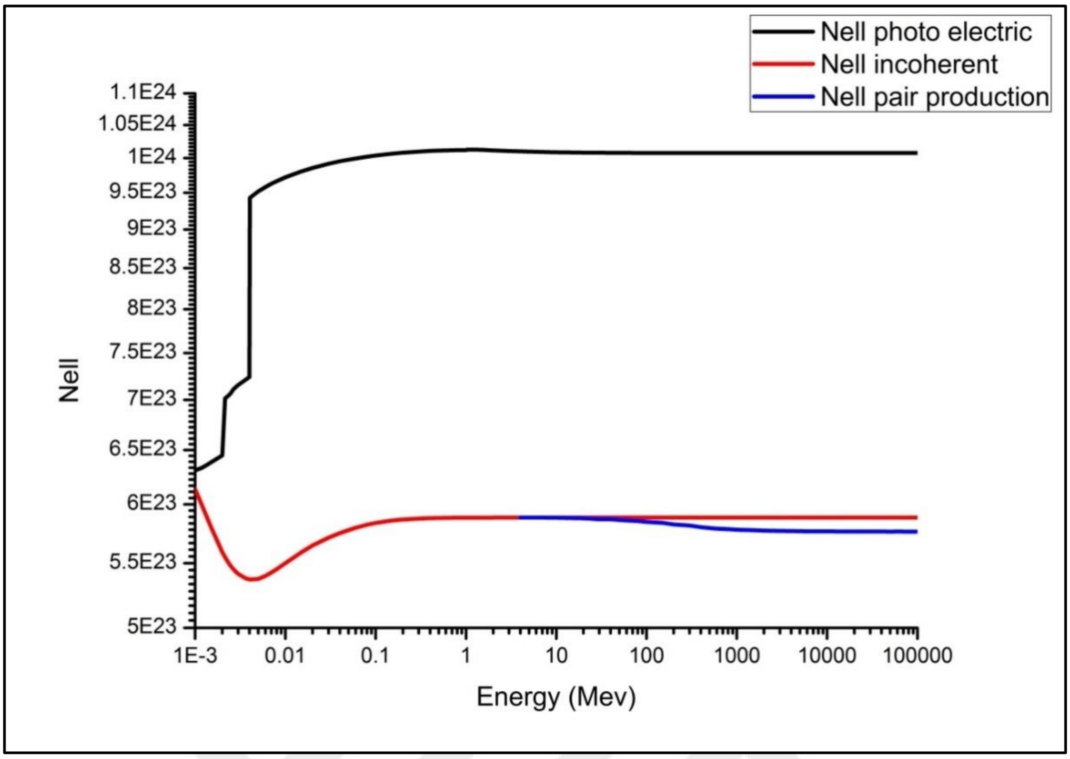


Figure 5.15 Electron density (N_{ell}) of skeleton corticalversus energy (MeV).

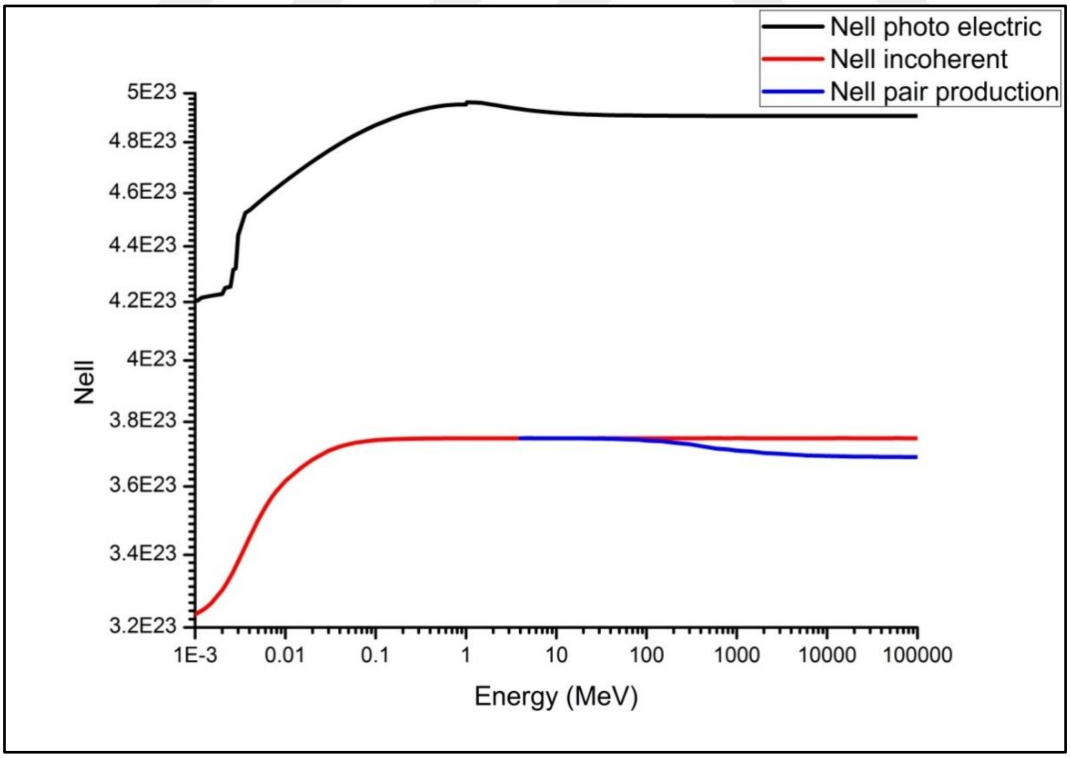


Figure 5.16 Electron density (N_{ell}) of skin tissue versus energy (MeV).

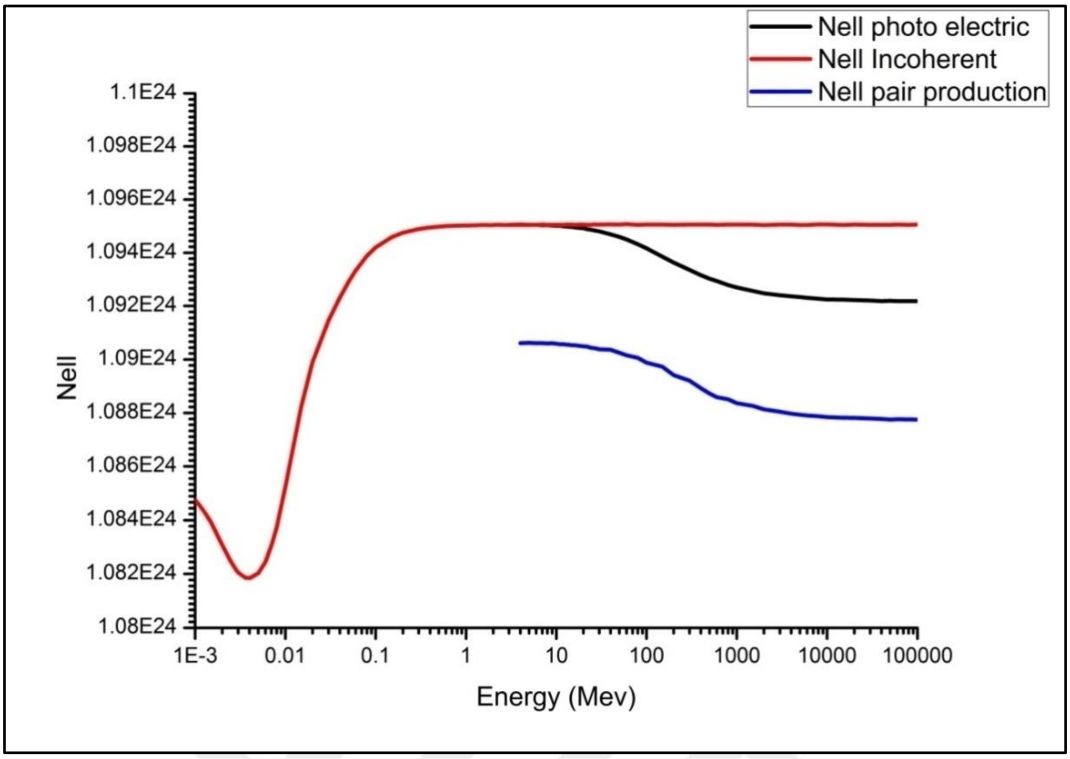


Figure 5.17 Electron density (N_{ell}) of soft tissue versus energy (MeV).

6. CONCLUSION

From the mass attenuation coefficient the figure shows three regations. From the mass attenuation coefficient the figure shows three rogations.

The photoelectric absorbing proses at low energies, the energy depends on μ_ρ complicated due to absorbing edge elements, in the energy range, the cross-section of the photoelectric effect dependents on the atomic number Z^{4-5}.

In incoherent scattering at intermediate energies, it is seen that there is a decrease in the values μ_ρ due to the linear dependence between the cross-section of incoherent scattering and atomic number Z.

In pair production at high energies since the probability of the pair production is directly proportional to Z^2, the values of μ_ρ increase slowly with the increment in photon energy.

It was found that the mass attenuation coefficient is less altered in the middle energy region where inconsistent dispersion is the most dominant operation, and inconsistent dispersion depends on linear Z dependence the significant variation in the mass attenuation coefficient in the high energy region is due to the pair production dependence Z^2. In some studies, those facts have been confirmed. After certain energy value (about 100 keV), the values of μ_ρ tend to be stable. In this analysis, WinXCom measured μ_ρ.

Only in this study, we find Z_{eff} successful atomic number of skeleton cortical high peak in the graph because the cortical skeleton weights fraction of the calcium atom (Ca=22.5) and the soft tissue is the highest value of Z_{eff} as it has an iron atom (Fe=0.2) fraction of the weight.

REFERENCES

David S. Chang, Foster D. Lasley, Indra J. Das, Marc S. Mendonca, Joseph R. Dynlacht, ***Basic Radiotherapy Physics and Biology***, (2014), 2014947114, USA New York.

Xie George Xu, (2010***), Handbook of Anatomical Models for Radiation Dosimetry***, 978-1-4200-5979-3, United States of America

Creagh, D.C., Hubbell, J.H., 1987. Problems associated with the measurement of X-ray attenuation coefficients. I. Silicon. Report of the International Union of Crystallography X-ray attenuation Project ***Acta Cryst. A.*** **43:** 102-112.

Hubbell, J.H., Seltzer, S.M., 1995. Tables of X-rays mass attenuation coeffecients and mass energy absorption coeffecients. ***National Institute of Standards and Technology- PL:*** **Gaithersburg, MD.**

Singh, K., Singh, H., Sharma, V. Nathuram, R., Khanna, A., Kumar, R., Bhatti, S.S., Sahota, H.S. 2002. Gamma-Ray attenuation coefficients in bismuth borate **Glasses*Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms***, 194: 1-6.

Chantler, C.T., Tran, C.Q., Barnea, Z., Paterson, D., Cookson, D Balaic, D., 2001. measurement of the X-ray mass attenuation coefficient of copper using 8.85–20 keV synchrotron radiation.***Physical Review A*, 64**: 062506.

Limkitjaroenporn, P. J. Kaewkhao, P. Limsuwan, W. Chewpraditkul, 2011. Physical, optical, structural and gamma-ray shielding properties of lead sodium borate glasses. ***J Phys Chem Solids*** **72:** 245-251.

Guru S., Prasad, K. Parthasaradhi, W.D (1998). Bloomer, Effective atomic numbers for photoabsorption in alloys in the energy region of absorption edges. ***Radiat. Phys. Chem*. 53**:449-453

Hine, G.J., 1952.The effective atomic numbers of materials for various gamma ray interactions.***Phys.Rev.*85**,725–737.

Berger, M.J. 1999 Hubbell, J.H. (1987).Measurements of radiological data of some amino acids in the energy range 0.122-1.330 MeV..***National Institute of standards and Technology, Gaithersburg, MD, originally published as NBSIR*** **87-3597 "XCOM: Photon Cross Sections on a Personal Computer"** .

Gerward, L. N. Guilbert, K.B. Jensen, H. Levring, 2001. X-ray absorption in matter. Reengineering XCOM. ***Radiat.Phys. Chem*** **60,** 23-24.

Manohara, SR, Hanagodimath, SM., (2007) Studies on effective atomic numbers and electron densities of essential amino acids in the energy range 1 keV–100 GeV. ***Nucl Instrum Methods PhysRes B Beam Interact Mater Atoms*** **258**:(2):321–328.

Manohara, S.R., Hanagodimath, S.M. 2008. on the effective atomic number and electron density: a comprehensive set of formulas for all types of materials and energies above 1 keV. ***Nucl. Instrum. Meth. B.*** **266***:* 3906-3912

Gerward, L.N.K. Guilbert, B. Jensen, Levring, H.2004. Photon attenuation characteristics of CoQ10 and resveratrol, ***Radiat. Phys. Chem*** **,71:** (*3),*653-654.

Gerward, L., Guilbert, N., Jensen, K.B., Levring, H., 2001. X-ray absorption in matter, reengineering XCOM**.** ***Radiat.Phys.Chem.*** **60:**23–24.

Akar, A., Baltas, H., Çevik U. Korkmaz F., Okumuşoğlu N.T (2005). Measurement of attenuation coefficients for bone, muscle, fat and water at 140, 364 and 662keV -

ray energies. ***Journal of Quantitative Spectroscopy and Radiative Transfer*****120**(2):203-211.

Akkurt, I. Akyildirim, H. Mavi, B. Kilincarslan, S. Basyigit, C. 2010. Gamma-ray shielding properties of concrete including barite at different energies. ***Prog Nucl Energy.*** **52**(1)620–623.

Akkurt, I., 2007, Effective atomic numbers for Fe-Mn alloy using transmission experiment. ***Chinese Phys Lett*** **24–10:**2812.

Akkurt I 2009, Effective atomic and electron numbers of some steels at different energies. ***Ann Nucl Energy*** **36**(11–12):1702–1705.

Akkurt, I., 2011, Determination of effective atomic number and electron density of chitin by gamma-ray attenuation**.** ***Int J Phys Sci*** **6:**5048–5050.

Kumar, A. Singh, S. Mudahar, G.S. Thind, K.S. (2007) Studies on effective atomic numbers and electron densities in some commonly used solvents, ***Nucl. Sci. Eng.*** **155,**102

Demir, D., Tursucu, A., 2012. Studies on mass attenuation coefficient, mass energy absorption coefficient and kerma of some vitamins. ***Ann Nucl Energy*** **48:**17–20.

Cevik, U., Baltas, H., Celik, S., Karaca, I., Kopya, A.I.,2005. Measurement of mass attenuation coefficients for YBaCuO super conductorat different energies. ***Su-percond. Sci.Technol*****.18,**101–106**.**

Cevik, U., Hasan, B., Ahmet, C., Emin, B., 2006.Determination of attenuation coef-ficients, thicknesses and effective atomic numbers for CuInSe2 semiconductor. ***Nucl.Instrum. Methods B*** **247:**173–179.

Kıran T. Kumar, S. Venkataratnam, K. (1996) Venkata Reddy, Effective atomic number studies in clay minerals for total photon interaction in the energy region 10 keV–10 MeV***, Radiat. Phys. Chem.*** **48**, 707-710.

Icelli,O. S. Erzeneoglu, I.H. Karahan, G. (2005). Cankaya,Linear Mass attenuation coefficient of Ni based alloys at energies 42.0 KeV and 59.54 KeV, ***J. Quant. Spectrosc. Radiat. Trans.*** **91**, 48

Murty,V.R.K. (2004) Gamma-rays shielding properties of xPbO:(100 − x) B2O3 glasses system at 662 keV, ***Radiat. Phys. Chem*****.** 71, 66..

Manjunathaguru, V. T.K. (2006) Umesh, Journal of Physics B: Atomic,Effective atomic numbers and electron densities of some biologically important compounds containing H, C, N and O in the energy range 145 1330 keV, ***Molecular and Optical Physics,*** **39(18),** 3969-3981

Singh, V.P. N.M. (2013). Badiger, Study of mass attenuation coefficients, effective atomic numbers and electron densities of carbon steel and stainless steels, ***Radioprotection*** **48 (3),** 431-443.

Jackson, D.J. (1981). Hawkes,X-ray attenuation coefficients of elements and mixtures**,** ***Phys. Rep*****.** 70, 169.

EXTENDED TURKISH SUMMARY

(GENİŞLETİLMİŞ TÜRKÇE ÖZET)

BAZI BİYOLOJİK DOKULARIN FOTON ETKİLEŞİM PARAMETRELERİNİN HESAPLANMASI

FATTAH, Rawa Kamaran
Yüksek Lisans Tezi, Fizik Anabilim Dalı
Tez Danışmanı: Doç. Dr. Rafet YILMAZ
Ocak 2020, -- sayfa

ÖZET

Bu tez çalışmasında, bazı biyolojik dokuların(adipoz doku, akciğer dokusu, kas dokusu, iskelet kıkırdağı, iskelet kortikali, deri dokusu, yumuşak doku) 1 keV-100 GeV enerji aralığında foton etkileşim parametreleri WinXcom kod programı kullanılarak hesaplandı. Bu paramtereler kütle soğurma katsayıları, etkin atom numarası (Z_{eff}) ve elektron yoğunluğu (N_{ell}). Bir maddenin kütle soğurma katsayısı (μ_{ρ}), verilen bir enerjide fotonun giriciliğinin bir ölçüsüdür. Bir dokunun, etkin atom numarasını ve electron yoğunluğunu hesaplamak için öncelikle kütle soğurma katsayısının değerleri hesaplanmalıdır. Bundan dolayı, 1keV-100 GeV enerji aralığında, bu biyolojik dokuların WinXCom kod programından kütle zayıflama katsayıları ($\mu\rho$) ile hesaplanmıştır. Daha sonra bu değerler kullanılarak. Etkin atom numarası ve elektron yoğunlukları hesaplanmıştır. Foton ile etkileşime giren farklı atom numaralarına sahip elementlerden oluşan bir kompleks malzemenin atom numarası, "aktif atom numarası" olarak adlandırılan bir parametre ile karakterize edilir. Kompleks maddelerdeki bu sayıya (Z_{eff}) denir. Etkin elektron yoğunluğu, bir malzemenin birim kütlesi başına elektron sayısı olarak tanımlanır ve N_{ell} ile gösterilir. Bu çalışmada, enerjiye karşı, kütle soğurma katsayıları, etkin atom numarası, electron yoğunluğu grafikleri çizilerek

fotoelektrik olay, comptan olayı ve çift oluşum olaylarının baskın olduğu bölgeler tespit edildi. Düşük enerji aralığında fotoelektrik olay, ortada Compton ve daha yüksek enerji aralığında çift oluşum olaylarının baskin olduğu görüldü. Bu üç baskın olayın herbiri için etkin atom numarası ve elektron yoğunlukları tekrar hesaplandı. Enerjiye karşı grafikleri çizilerek analiz edildi. Yine ayrıca, akçiğer dokusu ve kemik için deneysel çalışma yapıldı teorikdeğer ile karşılaştırıldı.

Anahtar kelimeler: Etkini atom numarası, Kütle soğurma katsayısı, , Elektron yoğunluğu.

MATERYAL VE YÖNTEM

Bu tez çalışmasında, bazı biyolojik dokuların (adipoz doku, akciğer dokusu, kas dokusu, iskelet kıkırdağı, iskelet kortikali, deri dokusu, yumuşak doku) 1 keV-100 GeV enerji aralığında foton etkileşim parametreleri WinXcom kod programı kullanılarak hesaplandı. Tablo 1 de biyolojik dokular görülmektedir.

WinXCom program

Berger ve Hubbell (1999) tarafından 1 keV-100 GeV enerji aralığında herhangi bir element, bileşik ve ağırlık yüzde miktarları bilinen karışımların kütle azaltma katsayılarını, atomik fotoelektrik olay, inkoherent saçılma, koherent saçılma ve çift oluşumu gibi kısmi foton etkileşim tesir kesitlerini hesaplamak üzere XCom adlı bir program geliştirilmiştir. Daha sonra, XCom programı Gerward *ve ark.,* (2001, 2004) tarafından Windows ortamına uyarlanarak WinXCom adı verilen Windows sürümünü geliştirmişlerdir. WinXCom programında tanımlanan ve kaydedilen materyalin verileri bir Microsoft Excel ortamına aktarabilmektedir. Dolayısıyla daha sonra yapılacak olan hesaplamalarda ve grafik çizimlerinde kolaylık sağlamaktadır.

Tablo 1. WinXCom kod programında kullanılan temel doku ve bileşimleri.

Atom	Yumuşak Dokusu (%)	Kas Dokusu (%)	Yağ Dokusu (%)	Deri Dokusu (%)	Akciğer Dokusu (%)	İskelet Kıkırdak (%)	İskelet Kortikal (%)
H	10.4	10.2	11.4	10.0	10.3	9.6	3.4
C	12.4	14.3	59.8	20.4	10.5	9.9	15.5
N	2.6	3.4	0.7	4.2	3.1	2.2	4.2
O	73.5	71.0	27.8	64.5	74.9	74.4	43.5
Na	0.2	0.1	0.1	0.2	0.2	0.5	0.1
Mg							0.2
P	0.2	0.2		0.1	0.2	2.2	10.3
S	0.2	0.3	0.1	0.2	0.3	0.9	
Cl	0.2	0.1	0.1	0.3	0.3	0.3	
K	0.2	0.4		0.1	0.2		
Ca	0.02						22.5
Fe	0.02						
ρ (g cm−3)	1.05	10.5	0.95	1.09	0.26	1.1	1.92

1. TEORIK HESAPLAMALAR

Bir maddeden geçen fotonlar soğurma ve saçılma nedeniyle zayıflar. Soğurmadan kaynaklanan zayıflama Beer -Lambert'in yasasına göre

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

Burada, I_0 and I gelen ve soğurulan foton yoğunluğudur. *d*birim alandaki kütle miktarı. (g / cm2) ve μ/ρ , foton kütle zayıflatma katsayısıdır (cm^2/ g). Tablo 4.1 de verilen biyolojik dokuların kütle soğurma katsayıları 1 keV ile 100 GeVenerji aralığında WinXCom kod program ile hesaplanır.

Herhangi bir kimyasal bileşik veya element karışımı için foton kütle zayıflama katsayısı,

$$(\mu/\rho)_C = \sum w_i (\mu/\rho)_i \quad (2)$$

Burada w_i ve (μ/ρ) kompleks i. maddenin ağırlık kesri ve kütle soğurma katsayısıdır.Kimyasal bir bileşik için (w_i) aşağıdaki gibi verilir.

$$w_i = \frac{n_i A_i}{\sum n_j A_j} \quad (3)$$

Burada $A_i$elementlerin atomic kütlesidir. n_i bileşikteki elementlerin atom sayısıdır. Bir kompleks bir maddenin etkin atom numarası aşağıdaki formülden hesaplanabilir.

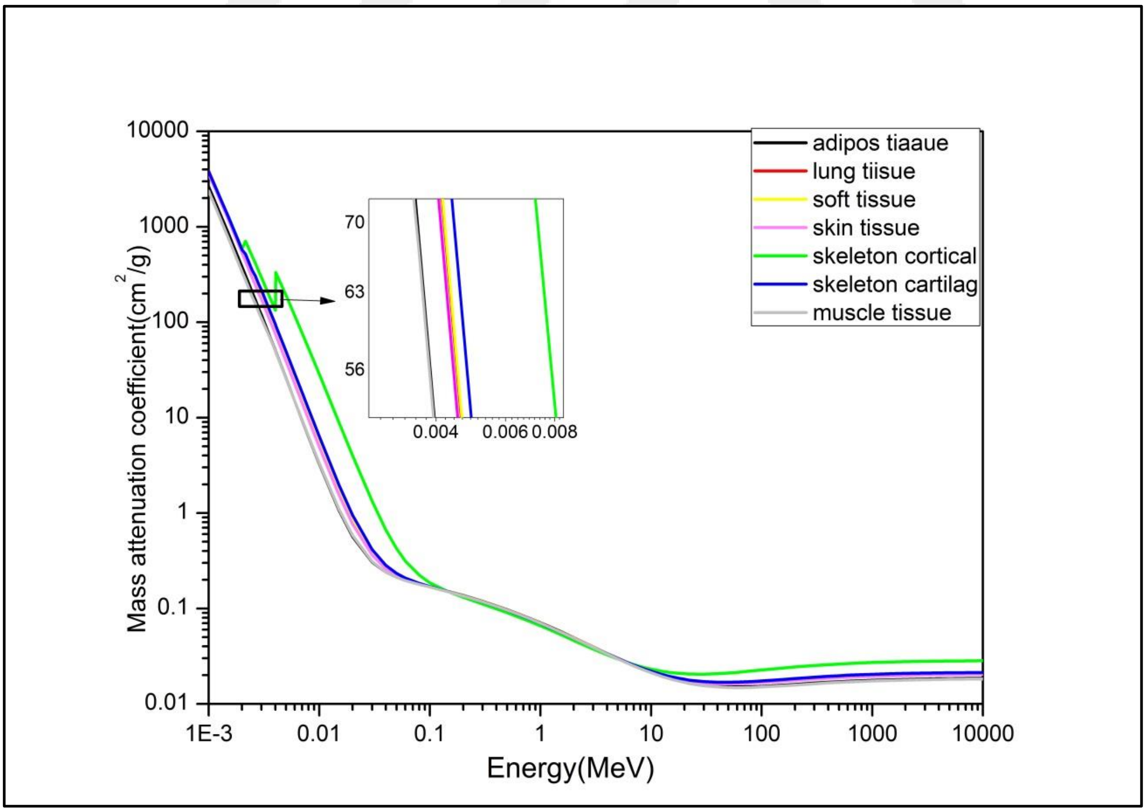
$$Z_{eff} = \frac{\sum_i f_i A_i \mu_i}{\sum_j f_j \frac{A_j}{Z_j} \mu_j} \quad (4)$$

Burada μ_i, verilen enerjide toplam kütle soğurma katsayısıdır. f_i kompleks maddedeki elemetlerin bolluk kesri. A bileşikteki elementin atomic kütlsi ve Z bileşikteki elementin atom numarasıdır. Elektron yoğunluğu, etkin atom numarası kullanılarak aşağıdaki gibi hesplanabilir.

$$N_{el} = N_A \frac{Z_{eff}}{\langle A \rangle} \qquad (5)$$

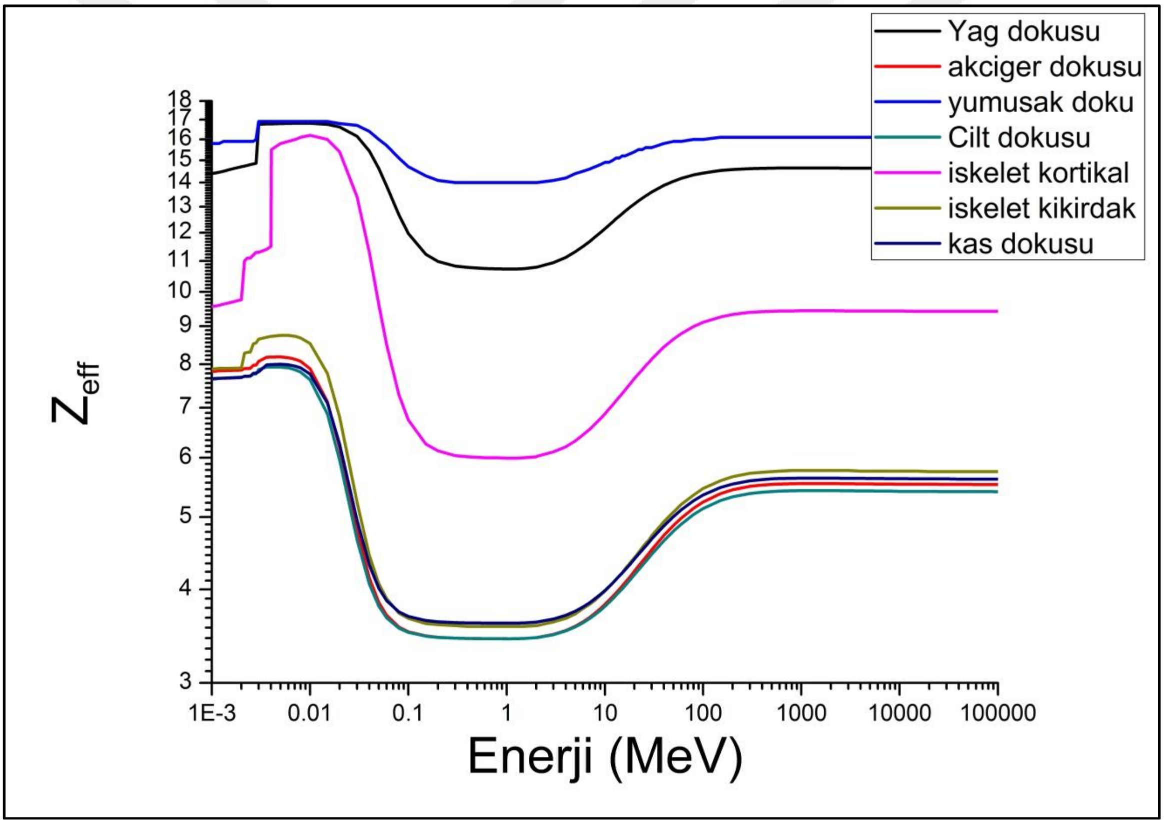
2.BULGULAR VE TARTIŞMA

Bu tez kapsamında WinXcom kod programı kullanılarak bazı biyolojik dokuların(yumuşak, kas, yağ, deri, akciğer, iskelet kıkırdak ve iskelet kortikal) 1 keV-100 GeV enerji aralığında WinXcom cod program kullanılarak kütle soğurma katsayıları hesaplandı. Daha sonra bu değerler yardımıyla biyolojik dokuların etkin atom numaraları ve elektron yoğunlukları denklem (4) ve (5) kulanılarak hesaplandı.Elde edilen değerler ile enerjiye karşı grafikleri Şekil 1-3 arasında görülmektedir. Şekil 1. de,etkili olan fotoelektrik,compton ve çift oluşum olaylarının baskın olduğu bölgeler görülmektedir. Düşük enerji bölgesinde fotoelektrik olay, orta enerji bölgesinde compton olayı ve daha yüksek enerjilerde çift oluşum olayları görülmektedir.



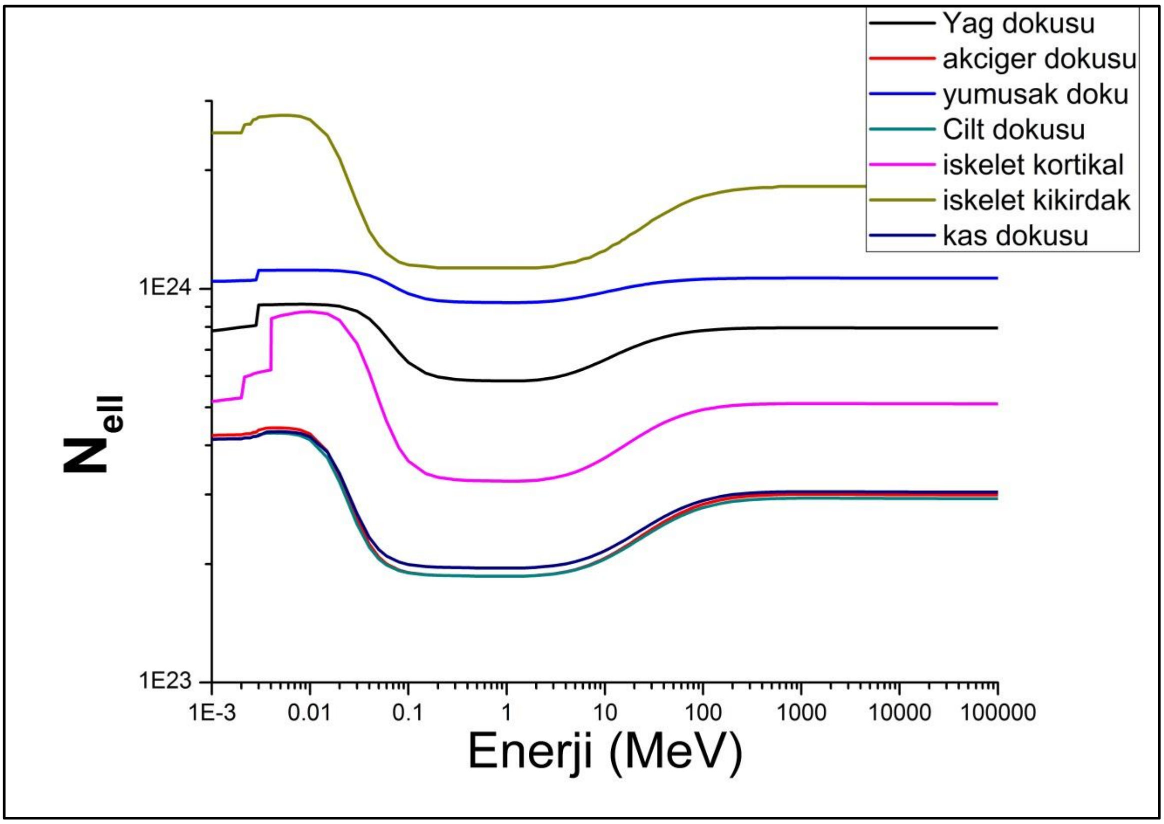
Şekil 1. Enerjiye(MeV) karşı kütle soğurma katsayıları (cm^2/g)

Şekil 1.de görüldüğü gibisoğurma kıyısı en belirgin doku kortikal kemiktir.Kütle soğurma katsayısı kemikte daha büyük olduğu görüldü. Bu ise kemiğin diğer dokulardan daha yoğun olduğu için ve atom numarası büyük olan elemente sahip olmasındandır.Genelde soğurma kıyısı belli olmayan doku yag dokusu olarak görülmektedir.



Şekil 2. Enerjiye(MeV) karşı etkin atom numarası.

Etkin atom numarası ve elektron yoğunluğu hemen hemen birbirine benzemektedir. Atom numarası daha büyük olan elemente sahip bileşiğin etkin atom numarası daha büyük olduğu görüldü. Aynı zamanda genel olara , yoğunluğu fazla olan bileşikler içinde hem etkin atom numarsı ve yoğunluk daha büyük olduğu görüldü



Şekil 3. Enerjiye(MeV) karşı electron yoğunluğu.

3. SONUÇ

Bazı biyolojik dokuların(yumuşak, kas, yağ, deri, akciğer, iskelet kıkırdak ve iskelet kortikal) toplam kütle azaltma katsayıları hesaplanıp grafikleri cizildiğinde fotoelektrik, comptan ve çift oluşum olaylarının baskın olduğu üç bölge tespit edildi. Fotoelektrik etkileşim, düşük enerji bölgesinde etkili olduğu ve bu enerji bölgesinde etkin atom numarası (Z_{eff}) maksimum değerlere sahip olduğu görüldü.Ayrıca fotoelektrik olayı Z^2 ile orantılı olduğuda görüldü. Compton saçılma olayının baskın olduğu orta enerji bölgesinde saçılma tesir kesiti Z ile orantılı olduğundan diğer foton etkileşim türlerine göre Compton saçılmasından kütle azaltma katsayısına gelen katkı en az olduğu için bu enerji bölegesine Z_{eff} değerleri minimumdur.Compton olayının Z ile orantılı olduğu görüldü. Çift oluşum olayının baskın olduğu yüksek enerji bölgesinde Z_{eff} değerlerinde zayıf bir artış gözlenmiştir. Bu artışın nedeni çift oluşum olayının gerçekleşme olasılığının Z^2 ile orantılı olarak değişmesidir. Dolayısı ile atom numarasının etkisinin Z_{eff} değerlerinde artışa sebep olduğu görülmüştür. Z_{eff} değerleri için yapılan yorumlar N_{el} değerleri içinde geçerlidir.

Bu çalışmalar, maddelerin radyosyon ile etkileşmeleri sonucu kütle soğurma katsayılarını, etkin atom numarası, elektron yoğunluğu hesaplamak, analiz çalışmalarında, özellikle tıp alanında teşhis ve tedavilerde oldukça önem arzetmektedir.

CURRICULUM VITAE

She was born in Iraq, in 1993 and She completed the primary and secondary education in Erbil.S studied in Salahaddin University, the college of Science, Department of Physics, in 2011 She graduated in September of 2015 She started her master study in Van Yuzuncu Yil University in 2018 .

T.C
VAN YÜZÜNCÜ YIL ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ
LİSANSÜSTÜ TEZ ORİJİNALLİK RAPORU

Tarih: 22/01/2020

Tez Başlığı / Konusu:

CALCULATION OF PHOTON INTERACTION PARAMETERS OF SOME BIOLOGICAL TISSUE

Yukarıda başlığı/konusu belirlenen tez çalışmamın Kapak sayfası, Giriş, Ana bölümler ve Sonuç bölümlerinden oluşan toplam 60 sayfalık kısmına ilişkin, 23/01/2020 tarihinde şahsım/tez danışmanım tarafından Turnitin intihal tespit programından aşağıda belirtilen filtreleme uygulanarak alınmış olan orijinallik raporuna göre, tezimin benzerlik oranı % 17dır.

Uygulanan filtreler aşağıda verilmiştir:

- Kabul ve onay sayfası hariç,
- Teşekkür hariç,
- İçindekiler hariç,
- Simge ve kısaltmalar hariç,
- Gereç ve yöntemler hariç,
- Kaynakça hariç,
- Alıntılar hariç,
- Tezden çıkan yayınlar hariç,
- 7 kelimeden daha az örtüşme içeren metin kısımları hariç (Limit inatch size to 7 words)

Van Yüzüncü Yıl Üniversitesi Lisansüstü Tez Orijinallik Raporu Alınması ve Kullanılmasına İlişkin Yönergeyi inceledim ve bu yönergede belirtilen azami benzerlik oranlarına göre tez çalışmamın herhangi bir intihal içermediğini; aksinin tespit edileceği muhtemel durumda doğabilecek her türlü hukuki sorumluluğu kabul ettiğimi ve yukarıda vermiş olduğum bilgilerin doğru olduğunu beyan ederim.

Gereğini bilgilerinize arz ederim. 23.01.2020

Tarih ve İmza

Adı Soyadı: Rawa Kamaran FATTAH

Öğrenci No: 17910002163

Anabilim Dalı: Fizik

Programı: Tezli

Statüsü: Y. Lisans ☒ Doktora ☐

DANIŞMAN ONAYI
UYGUNDUR

Doç. Dr. RAFET YILMAZ

ENSTİTÜ ONAYI
UYGUNDUR

Prof. Dr. ... SOY
Enstitü Müdürü