Calculation of Atomic Cross section &Electron Density for (Tissue and Bone) using Monte Carlo program

حساب مساحة المقطع العرضي الذري والكثافة الكترونية لــ (الانسجة والعظام) باستخدام برنامج مونت كارلو

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Abstract

In the present work , calculated mass attenuation coefficients ,atomic cross section and electron density for these tissue and bone were theoretically calculated using monte carlo program within a range of energies of x-rays (16.5-17.5-21.5-24.5)keV .The attenuation coefficient of substances ,at any energy of x-ray photon ,is known to depends on the electron density and effective atomic number of the material .which makes it very sensitive to the index "x" .Several different values laying between (0.5 - 2.5) step 0.5 have been suggested for the exponent "x".The results were compared with XCOM program .These theoretical values are found to be in agreement with the calculated from XCOM value .

Keywords: Monte Carlo program, XCOM package, mass attenuation coefficient, electron density.

الملخص:

في هذا البحث،حسبت معاملات التوهين الكتلية ـ المساحة المقطع العضي الذري وكذلك الكثافة الالكترونية للانسجة والعظام باستخدام برنـامج مونت كارلو ولمدى الطاقـــات الاشعة السينية (16.5-17.5-21.5-24.5)keV.وتم فرض الاسماك المختلفة لمواد المذكوره اعلاه ،اظهرت النتائج ان المعامل التوهين يقل بزيادة الطاقة الاشعة السينية .وقورنت البيانات البحث الحالي مع برنامج (XCOM) (Version 3.1) وكانت هناك توافق جيد في الحسابات .

الكلمات المفتاحية: الأشعة السينية ،الكثافة الكترونية،المساحة المقطع العرضي الذري.

1-Introducation:

The mass attenuation coefficient is a measure of the average number of interactions between the incident photons and the matter that occur in a given mass per unit area thickness of material encountered .The mass energy absorption coefficient on the other hand, is a measure of the average fractional amount of incident photon energy transferred to kinetic energy of charged particles as a result of these interactions. This imparted, charged particles kinetic energy is, in turn, a more or less valid approximation to the amount of photon energy made available for the production of chemical, biological, and other effects associated with exposure to ionizing radiation. The mass energy absorption coefficient has thus assumed an essential role in estimating absorbed dose in medical and health physics [1].In order to select the most suitable material for radiation dosimetry ,the characteristics of the various materials must be know [2,3].The attenuation of x-ray by material provides a rich diagnostic tool for testing our understanding of the fundamental properties of matter in the atomic , molecular , or solid state .Relative and absolute measurements of the mass attenuation coefficient test theoretical prediction of photoelectric absorption and form factor [4-5],investigate the dynamics of atomic processes , including shake –up, shake-off ,and other Auger transitions [6-9],and provide information on the density of electronic states [10].Molecular bonding ,and other solid state properties [11]. The total mass attenuation coefficients (μ/ρ) for pure Au and $Au_{99}Be_1$, $Au_{88}Ge_{12}$ and $Au_{95}Zn_5$ alloys were measured at 59.5 and 88 keV photon energy [12].Detemined total mass attenuation coefficient for 21 different compounds at 59.54 keV using a narrow beam good geometry setup [13].

2-Methodology:

To determine the therapeutic aspects and decision-making by using radiation therapy has a number of measurements in order to careful planning for the field of radiation therapy. So is the process of visualization and simulation prior to treatment. It is well known that the theory of measurements is always give perfect results when you perform a simulation process. In addition, may be sometimes there are accounts did not take into consideration the researcher during the process taking measurements the exact. And (Monte Carlo method) of fine ways to get better results in the field of radiation [10]. In this research was to used of the program, we have already mentioned in a mathematical process to measure intensity of the x-rays inflicted and outflow of samples with proven of the angle between the detector and the thickness of the material within the range of energies of the emitted X-ray tubes.

a) Mass attenuation coefficient:

As a photon makes its path through a matter there is a probability that it makes an interaction with the material such as absorption (photoelectric effect) , scattering (Rayleigh or Compton scattering) or splitting (pair production).Therefore ,part of the incident beam of intensity (I_0) will be partially or completely removed from the beam as a result of interactions within the absorber of thickness x.this reduces the transmitted intensity that reaches the detector to (I) ,where ,introducting the linear attenuation coefficient ,the transmitted intensity is given by ;

$$\mu_L = \ln(I_0 \, / \, I)/x \qquad (1)$$

This is called the Beer –Lambert law ,where $(\mu)_i$ measured in units of length^{-1} which describes the probability of absorption or scattering occurring per unit length within the absorber material [14].The exponential means that equal thickness of the absorber attenuates the photon beam by an equal fraction or percentage [15]. The total mass attenuation coefficient $(\mu/\rho)_C$ for any chemical compound or mixture of elements is given by mixture rule [16];

$$(\mu/\rho)_C = \sum_i w_i(\mu/\rho)_i \qquad (2)$$

Where w_i and $(\mu/\rho)_i$ are the weight fraction and mass attenuation coefficient of the i-th constituent element, respectively. For a chemical compound the fraction by weight (w_i) is given by

$$w_i = \frac{n_i A_i}{\sum_i n_i A_i} \qquad (3)$$

Where A_i is the atomic weight of the *i*th element and n_i is the number of formula units.

b) Cross section:

The cross-section can be defined as the probability of an interaction to occur, it has the dimension of area in units of barn abbreviated $b = 10^{-28}$ m^2 = 10^{-24} cm^2 .There are different kinds of cross-sections; atomic, molecular and electronic cross-sections. The atomic cross-section for an element of atomic weight A is given by:

$$\sigma_a = \frac{\mu}{\rho}\frac{A}{N_{av}} \qquad (4)$$

N_{av} represents the Avogadro's number. For a compound the molecules of which have n_i atoms for the i-th element, the atomic or molecular cross-sections are given by:

$$\sigma_a = \frac{\mu}{\rho}\sum_i \frac{n_i A_i}{\sum n_i}\frac{1}{N_{av}} \qquad (5)$$

The electronic cross-section for an element is given by:

$$\sigma_e = \frac{\sigma_a}{Z} \qquad (6)$$

Hence, for the compound, the electronic cross-section is

$$\sigma_e = \frac{1}{N_{av}} \sum_i \left(\frac{f_i A_i}{Z_i}\right) \left(\frac{\mu}{\rho}\right) \qquad (7)$$

where fi (= $n_i/\Sigma n_j$) is the fractional abundance of element i, with respect to the total number of atoms. Z_i: is the atomic number of the element. The effective atomic number (Z_{eff}) is a property for a compound, it describes the properties of the composite materials in terms of equivalent elements.It represents the weighted average atomic number of the compound composed of different materials. The average is weighted according to the relative number of each type of atom, Z_{eff} value of a material varies within a range with lowest and highest atomic numbers of its constituent elements [17].

The effective atomic number is equal to:

$$Z_{\text{eff}} = \frac{\sigma_a}{\sigma_e} \qquad (8)$$

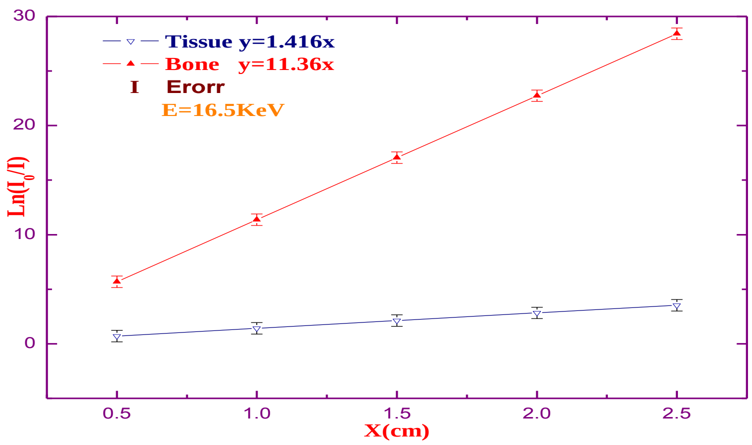
The electron density can be defined as the number of electrons per unit mass, and it can be mathematically written as[18]:

$$N_{el} = \frac{(\frac{\mu}{\rho})_c}{\sigma_e} \qquad (9)$$

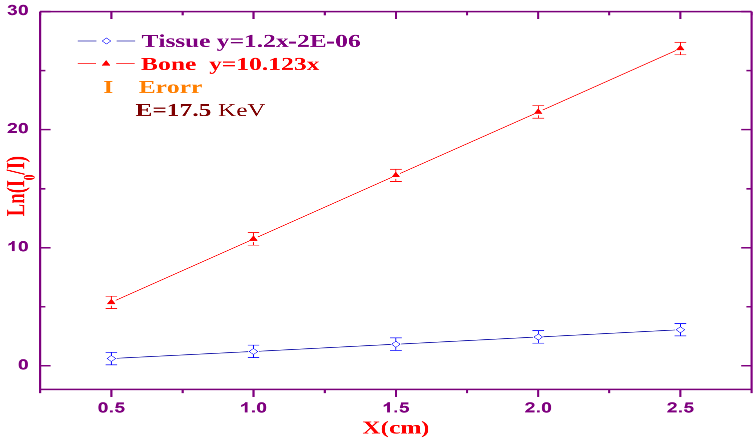
where N_{el} represents the electron density in unit of electron/gram, $(\mu/\rho)_c$ is the compound mass attenuation coefficient and σ_e is the electronic cross-section.

3-Results and Discussion:

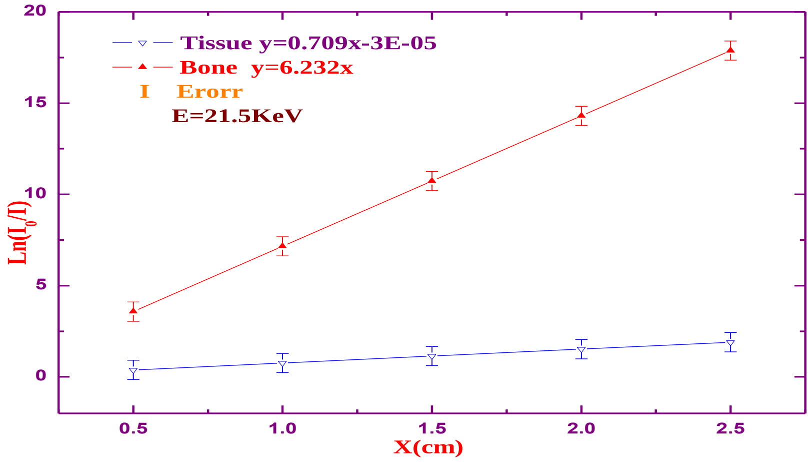
From the graphs ,the linear attenuation coefficient quantity (μ_L)is determined by measuring the incident photons intensity (I_0) and the intensity (I) of the photons after passing through samples with thickness (*x*).A graph of $\ln(I_0/I)$ versus thickness (*x*) is drawn, a linear relation appears, the slope of the linear equation represents the value of the linear attenuation coefficient.



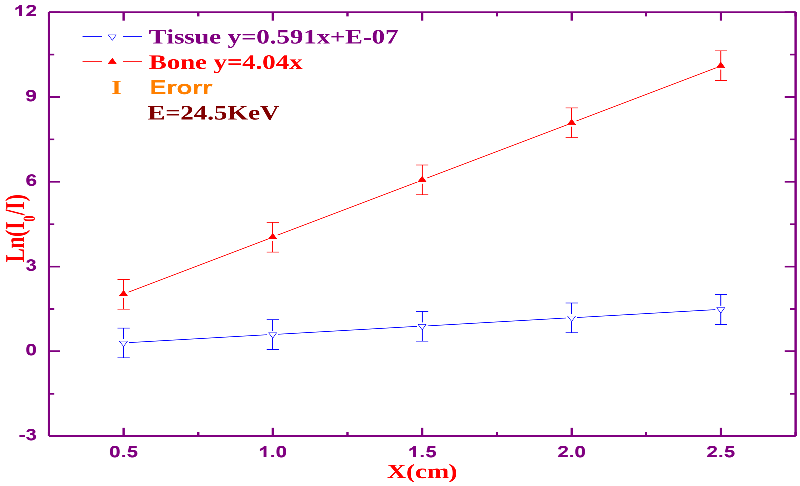
Fig(1):linear attenuation coefficient for Tissue and Bone using 16.5 keV.



Fig(2):linear attenuation coefficient for Tissue and Bone using 17.5 keV.



Fig(3):linear attenuation coefficient for Tissue and Bone using 21.5 keV.



Fig(4):linear attenuation coefficient for Tissue and Bone using 24.5 keV.

Table (1):Comparison linear attenuation coefficients for Tissue and between present work and XCOM. Bone

E(keV)	Tissue		Bone	
	μ_L(cm^{-1}) present work	μ_L(cm^{-1}) XCOM	μ_L(cm^{-1}) present work	μ_L(cm^{-1}) XCOM
16.5	1.416	1.57	11.36	11.33
17.5	1.221	1.421	10.123	10.05
21.5	0.709	0.952	6.232	6.22
24.5	0.591	0.705	4.042	4.33

Table (2): Comparison of mass attenuation coefficients of Tissue and Bone between the present work and XCOM.

E (keV)	Tissue		Bone	
	μ_m(cm^2/gm) present work	μ_m(cm^2/gm) XCOM	μ_m(cm^2/gm) present work	μ_m(cm^2/gm) XCOM
16.5	1.3363	1.482	6.89	6.868
17.5	1.1522	1.341	6.135	6.092
21.5	0.7168	0.898	3.776	3.769
24.5	0.5583	0.665	2.45	2.63

Table (3):The atomic cross section for Tisse and Bone calculation by Monte Carlo program and with XCOM program.

E (keV)	Tissue (Z=7.5)		Bone (Z=13.8)	
	(σ_a) $cm^2/atom$		(σ_a) $cm^2/atom$	
	present work	XCOM	present work	XCOM
16.5	3.01388E-23	3.3425E-23	2.98978E-22	2.9802E-22
17.5	2.59866E-23	3.0245E-23	2.66216E-22	2.6435E-22
21.5	1.61666E-23	2.0253E-23	1.63852E-22	1.6355E-22
24.5	1.25918E-23	1.4998E-23	1.06313E-22	1.1412E-22

Table (4):The electron density for Tisse and Bone calculation by Monte Carlo program and with XCOM program.

Tissue (Z=7.4)		Bone (Z=13.8)	
(N_{el})electron/gram		(N_{el})electron/gram	
present work	XCOM	present work	XCOM
3.54706E+23	3.54706E+23	3.13414E+23	3.18E+23

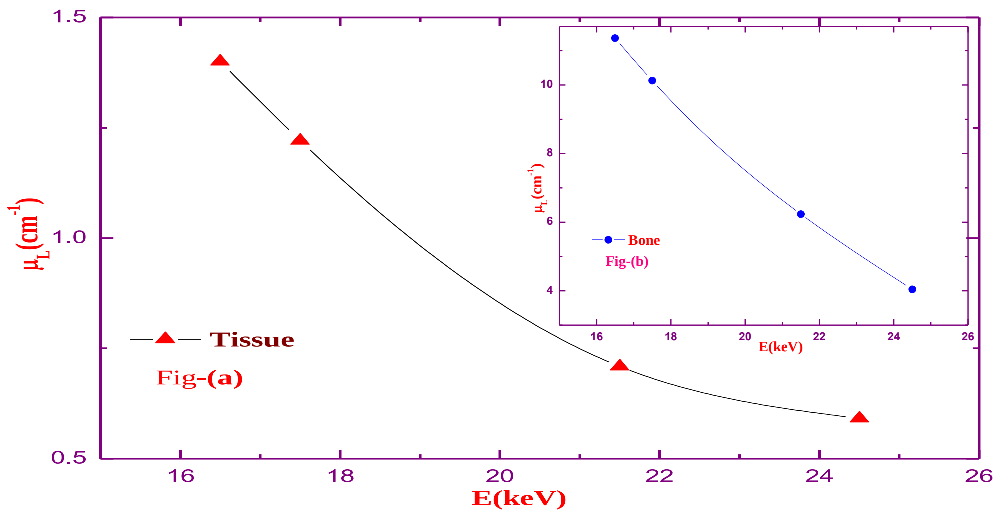


Fig (5): linear attenuation coefficient versus energy For: a) Tissue, b) bone.

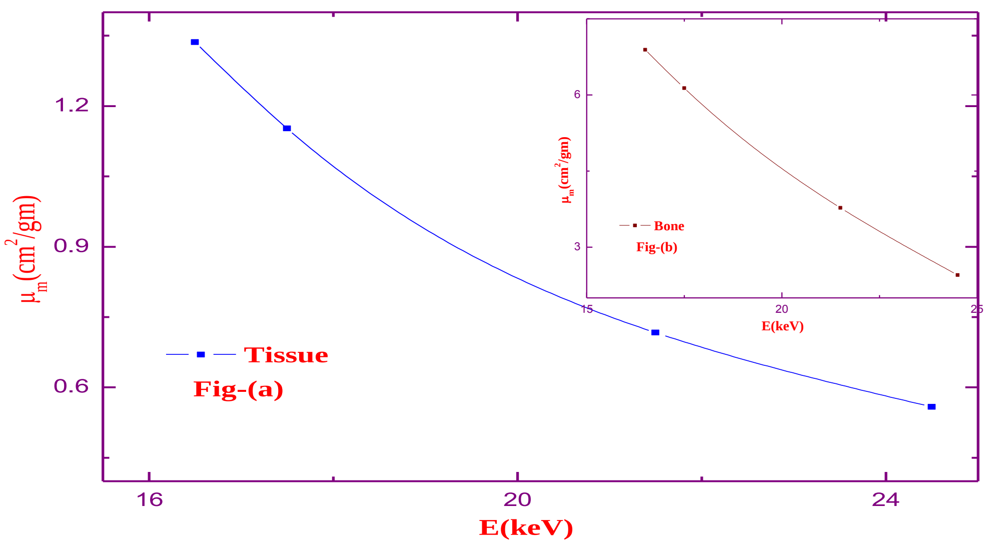


Fig (6): Mass attenuation coefficient versus energy for :a)Tissue , b)bone.

Table (1&2), show values (μ_L, μ_m) calculated using Monte Carlo program compared with results determined XCOM package.It is clearly seen that the mass attenuation coefficients depends on the photon energy and the concentration of elements within materials .In the same table ,it is concluded that addition of various amounts of different metals influence on the (μ_m) .There are differences in mass attenuation coefficients for different element inclusive (Tissue, bone).The value (μ_L, μ_m) for bone of this work compared with XCOM value are in good agreement, but (μ_L, μ_m) value for almost in the Tissue studied in the present work are smaller than their XCOM value. The high values of XCOM return to the effect of chemical composition of the sample. In the same tables, it is observed that, as (μ_L, μ_m) decreases with increasing photon energies ,this confirms the contribution of the absorption process photoelectric effect, scattering process (Compton coherent and pair production).From table (3) show measured total atomic cross –section for present material .The change σ_a show almost similar behavior to attenuation coefficient .Atomic cross –section values decrease with photon energy because probability of absorption reduces with incident photon energies. Atomic cross-section which is represented by Tissue and bone in this work ,has relationships with atomic weight and mass attenuation .The electron density values for present sample were determined using $(\mu/\rho)_c$ and σ_e values and given in table (4).This is also shown in Figure (5,6) for Tissue , bone respectively .From the results ,it can be concluded that (μ_L, μ_m) of samples vary within photon energy .

4-Conclusion:

The mass attenuation coefficient of the tissue and bone have been measured employing x-ray emitted from several tubes using Monte Carlo program .This results study has been undertake to get some information on the (μ_L, μ_m) and related parameters atomic cross-section ,electronic cross-section and electron density for materials at different energies . From the data ,show bone appears as a good attenuator .In the present work, the cross –section value for all energies are very close to with XCOM results which mean the probability of interaction is approximately the same. On the other side, the values electron densities for the samples are found to be in this paper compatible both theoretical measurments.The scattering and absorption of x-rays radiations is related to the density and atomic number of an element, while it is related to density and effective atomic number composite materials .

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