Study of Collision and Radiative Stopping Power of Electron for Blood, Bone, and Adipose Tissue

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Abstract--- *The mass collision stopping power (dE/ρdx)col, the mass radiative stopping power (dE/ρdx)rad and the total mass stopping power of electrons in the energy range of (0.01 – 1000) MeV has been calculated for Blood, Bone and Adipose Tissue. The results of the present work for the collision stopping power of electrons in Blood, Bone and Adipose Tissue are in good agreement with the standard results given by ESTAR program. The radiative stopping power of electrons in the same energy range is also calculated using a modified equation, and the results are found to be in agreement with the standard published values. The employed modified equation used to calculate the radiative energy loss of electrons is valid in the energy range of electrons from (0.01–1000) MeV and gives accurate results. As the results of total stopping power calculation are concerned, they are found in good agreement with the published results, where the error is less.*

Keywords--- *Electron Stopping Power, Radiative Energy Loss, Total Energy, Human Body Tissues.*

I. INTRODUCTION

When charged particles pass through the matter, they lose part of their energy continuously in a large number of collisions and charged particles that penetrate the material and collide and feed the atomic electrons and are released rapidly (v), with charge (Z1 e) and mass (m) [1]. The ways in which charged particles lose their energy when passing through different media, such as gases, liquids and solids, are the interaction between fallen particles and the atoms of these media. These reactions can be divided into four reactions [2-5]. These reactions could be either reactions of heavy charged particles with matter which in turn are classified into two groups: Heavy charged particles with atomic number $Z1<2$ such as protons. Heavy charged particles that number $Z1 \geq 2$ atomic, such as alpha particles and fission fragments [6]. The second type could be reaction of light charged particles such as (electrons and positrons). The third type reaction of gamma rays with the substance. The fourth is the neutron reaction with material [7].

The important quantity that we have to deal with is the stopping power - dE/dx (known as the average energy loss by the particle per unit path length8 .that the process of loss of energy from the charged particles has been and continues to take a broad interest in the fields of atomic physics and nuclear and all science fields9, the first to develop a special theory of calculating the stopping power in collisions between charged heavy particles and electrons is Bethe in 1930-19323. The passage of electrons through the material media is similar to the passage of heavy charged particles through the physical medium, i.e., the Coulomb reaction is dominant, yet there are three obvious differences that can be easily seen10:

1. Falling electrons are usually relative particles.

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2. Dispersion is often between identical particles and inconsistent.
3. Interact with effective nuclei, electron direction is possible that changes to reverse, when colliding with a heavy nucleus. The interaction of electrons with matter is more complex than the reaction of heavy charged particles with matter 3is because:

1. The falling electron and electrons are present within the material has the same mass, there will be more polarization of the electron falling (cannot know which one was the electron falling and for this the length of the course during the material can be much greater than the straight line or the length of the range.
2. The charge of the falling body does not change at all, so the loss of energy by the ion is very large for the energies that reach the limits of electron volts. this causes gaps at the end of the electron path
3. That the electrons with certain kinetic energy are faster than the speed of the heavy particles of the same energy and therefore the loss of the energy of electrons by the emission of electromagnetic radiation remains important at much lower energies than those that are for protons for example [2].

II. THEORY/CALCULATION

T If the energy of the electron enters the material is very small, it will pass without any significant effect on the molecules of the material [11], but if its energy is determined by this it is likely to give its energy to the atoms of the atom according to the sight of Bohr, which leads to excitation to higher energy levels or occur ionization4. It is find that the rate of loss of energy electrons in Materials [12]:

$$(-dE/dx)_{tot} = (-dE/dx)_{col} + (-dE/dx)_{rad} \quad \ldots\ldots\ldots(1)$$

There are two basic processes in which the electron loses its energy when passing through the material media:

Loss of energy by inelastic collision with atom electrons, and to know the amount of energy lost in the inelastic collision between fallen electrons and the atom electron using the formula developed by Mott in 1930/49 for low energies. Meanwhile in high energies, all relative corrections must be added to the Mottequation [3].

The theoretical value can be obtained for stopping power of electrons when their energy is small compared with its rest energy ($E<m_ec^2$) and as in the following relationship [13]:

$$(-dE/dx)_{inel} = \frac{4\pi e^2}{m_e v^2} ZN \left[\ln\frac{m_e v^2}{2I} + 0.15\right] \ldots\ldots\ldots(2)$$

However when the energy of the electrons (E) is larger than ($E> m_e c^2$) the theoretical value of the stopping power is [13]:

$$(-dE/dx)_{inel} = \frac{2\pi e^2}{m_e c^2} ZN\left[\ln \frac{m_e c^2}{2I} + 0.15\right] \ldots\ldots\ldots(3)$$

Loss of energy by radiation, that electrons of high energy may reach a distance approaching the atomic orbit as a result of the impact of the power of Colombian gravitation (F) between electrons and the nucleus when approaching this distance, called the impact parameter [14]. This deviation is accompanied by the emission of photons whose total energy is part of the energy of the falling electron [15]. This is because the nucleus tries to stop the electrons by the power of the Colombian , but the electron gets accelerated as a result of the electromagnetic field of the nucleus which is accompanied by the acceleration of the emission of radiation called Bremsstrahlung (braking radiation) [7] these rays come out as a result of the deviation that occurs in the course of the electrons, which leads to acceleration

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when encountered on the way nuclei or atomic electrons [3] to calculate the energy lost by the electron in the form of radiation decay on the unity of the length of the path within the material used the following relationship [13].

$$(-dE/dx)_{rad} = (4Z(Z+1)e^{4})/(137 m_e^{2} c^{2})\, NE[\ln(183\, Z^{-1/2}) + 0.125 \quad \text{.....(4)}$$

This relationship represents the stopping power by radiation is valid as long as the energy of electrons is large i.e. $(E > mec^2)$.

The inelastic energy losses by an electron moving through a medium with density ρ are described by the total mass energy stopping power $(dE/\rho dx)_{tot}$, which represents the kinetic energy Ek loss by the electron per unit path length x, or:

$$(dE/\rho dx)_{tot} = 1/\rho \ (dE_k)/dx (MeV.cm2/g) \qquad \text{.....(5)}$$

$(dE/\rho dx)_{tot}$ consists of two components: the mass collision stopping power $(dE/\rho dx)_{col}$, resulting from electron–orbital electron interactions (atomic excitations and ionizations), and the mass radiative stopping power $(dE/\rho dx)_{rad}$, resulting from electron–nucleus interactions (Bremsstrahlung production) [16]:

$$(dE/\rho dx)_{tot} = (dE/\rho dx)_{col} + (dE/\rho dx)_{rad} \qquad \text{.....(6)}$$

The Stopping Power calculation for electrons pass through matter is similar to that for heavy charged particles. The interaction of incident electrons with atomic electrons, leading to excitation and ionization, can be calculated from Bethe's theory, and it is called the 'Collisional Stopping Power' [17]. In addition to that, electrons are accelerated in the Coulomb field of nuclei, and this leads to electromagnetic radiation, the so-called "Bremsstrahlung". The corresponding stopping power is the 'Radiative Stopping Power' [18].

III. Results And Discussion

The results of the present work for mass collision stopping power of electrons in Blood, Bone and Adipose Tissue were in excellent agreement with the ESTAR program the maximum percentage error between the present work values and that of ESTAR cod in Blood, Bone and Adipose Tissue, where the error was very low and less than 1%. Figs. (1, 2, 3).

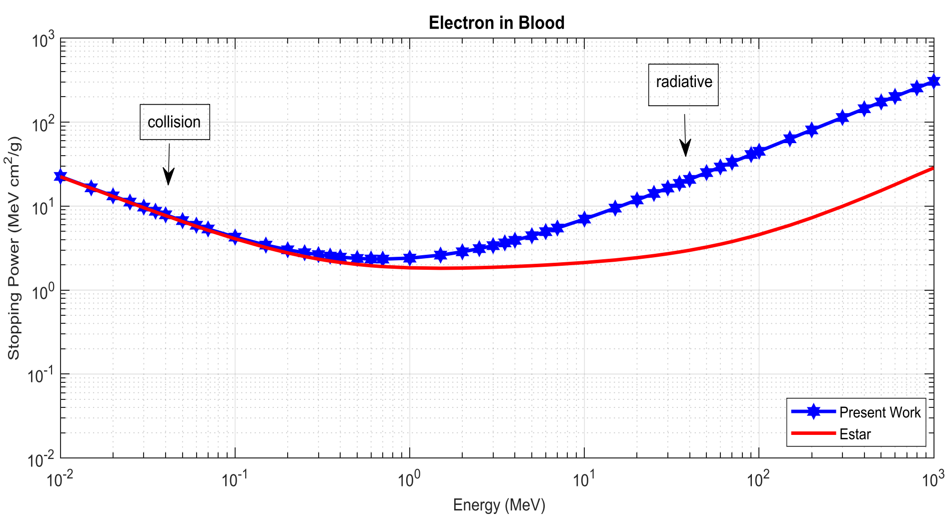

Fig. 1: Comparison of the present work and ESTAR results for collision stopping power and radiative in the Blood

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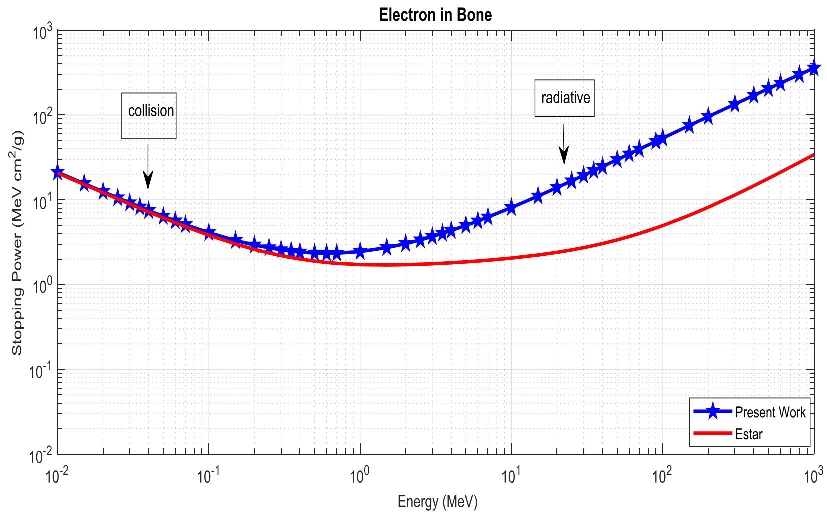

Fig. 2: Comparison of the present work and ESTAR results for collision stopping power and radiative in the Bone

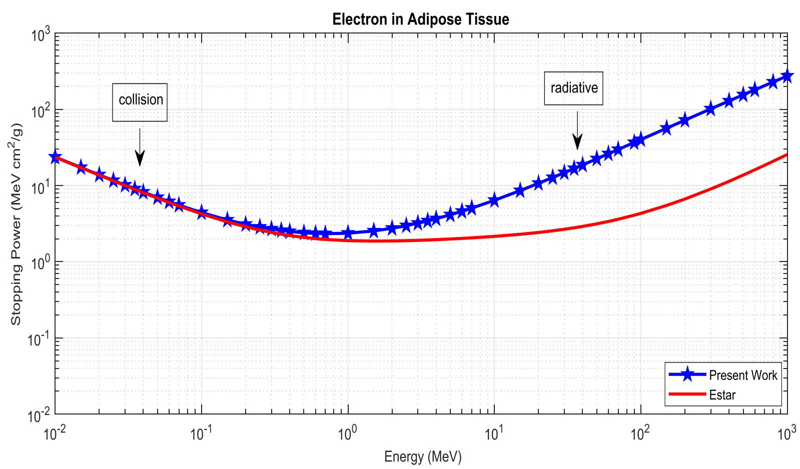

Fig. 3: Comparison of the present work and ESTAR results for collision stopping power and radiative in the Compound Adipose tissue

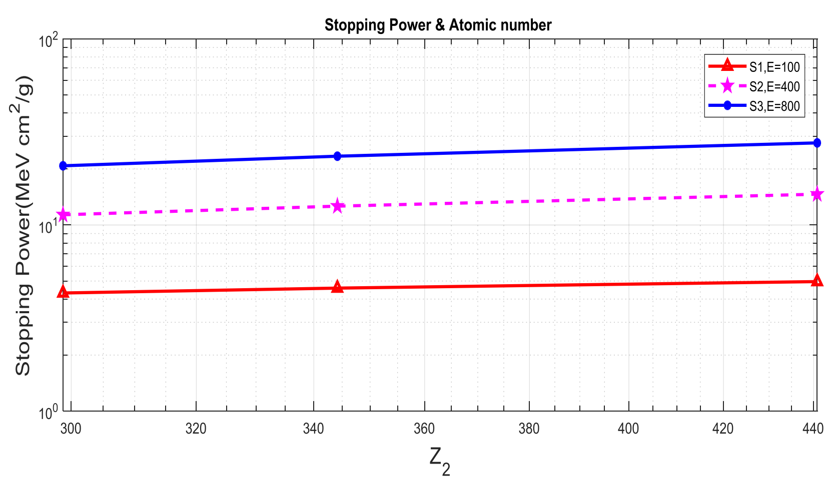

Fig. 4: Relationship between the stopping power of electron and the atomic number (Z_2) of targets studied in the research (Blood, Bone, Adipose Tissue) at energies (100,400,800)MeV

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The mass radiative energy loss of electrons in the same energy range we observe that the behavior is the same behavior , but there is a difference between the theoretical results and the results of the global program ESTAR and explains that according to the laws of electrodynamics, when the acceleration of a charged particle ,this body emits electromagnetic radiation where it fits the square of the wheel and when passing electron near the nucleus of charge Ze its path deviates and this deviation is accelerated and this results in the acceleration of electromagnetic radiation ,known as the Bremsstrahlung (braking radiation), which leads to the loss of electrons to a part of its energy . This energy loss occurs not only on the nucleus of the atom but also on the orbital electrons. From Fig.4 we observe that the correlation between the atomic number of studied targets and the stopping power of electron is positive. The figure shows that the atomic number of target the greater the stopping power of the electron.

IV. CONCLUSION

It is well known that the ionization value in tissues is proportional to cells damage. Therefore, the main aim of this study is to evaluate electron energy deposition in target organ and in various entrance layers (Blood, Bone, and adipose tissue). We used the energy that varies between 0.01 and 1000MeV, and obtained the stopping power diagram for each energy beam using the ESTAR cod. The collision and radiative stopping power is proportional to Z_2. ($dE/\rho dx$) increases rapidly at low energies reaches a maximum and decreases gradually with increasing energy. The stopping power allows to calculate the range of the electrons particles in the absorber material. Heavy particles are less scattered than electrons due to their heavy masses and the beam shows significantly better spatial resolution. Because of the specific energy dependence of the energy loss (or stopping power curve) incoming high energy particles experience only little energy loss dE/dx, but the energy loss maximizes when particles have slowed down to energies which correspond with the peak of the energy loss curve.

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