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CALCULATION OF THE STOPPING POWER OF ALPHA PARTICLES AND ITS RANGE IN BONE TISSUE

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Abstract

With the advancement of modern radiotherapy technology, radiation dose and dose distribution have significantly improved. as part of Natural development, interest has recently been renewed by treatment, especially in the use of heavy charged particles, because these radiation types serve theoretical advantages in all biological and physical aspects. The interactions of alpha particle with matter were studied and the stopping powers of alpha particle with Bone Tissue were calculated by using Zeigler's formula and SRIM software, also the Range for this particle were calculated by using Mat lab language for (0.01-1000) MeV alpha energy.

Keywords: Stopping Power; Range; Ziegler; SRIM; Alpha Particle; Bone Tissue.

1. Introduction

The stopping power is the rate of loss of energy per unit length (dE/dx). It depends on the speed and charge of both the fallen particles and the target material. [1,2].

The loss of energy and the range of particles or ions in the air, tissues and polymers are very important in most researches and applications such as radiation science such as blood cancer, cell alteration, radiation mutations, nuclear physic [3,4]. The calculation of stopping power is one of the most important calculations in reducing the damage that radiation may cause to tissue adjacent to the infected tissue during radio therapy. Chemical composition of breast tissue with fracture weight to each element (H=0.056, C=0.093, N=0.033, O=0.0394, Na=0.004, P=0.134,k=0.002 and Ca=0.280,Mg=0.004)[5].

2. Theory

The values of stopping power can be obtained using the SRIM program, as this program can calculate the stopping power, the range and the distribution of the ion in any atomic target quickly and presents the results in tables.[6]. The other method used in this work to calculate stopping power is Ziegler's formulae. In this method the loss of energy is divided into two parts: the first is the loss of electronic energy and the second is the flexible energy loss of the nuclei. In this research, the stopping power was calculated using the Ziegler's equation for high and low energies, were published as the reference [7]. The loss of energy for a compound or tissue consisting of several thin layers of pure elements is calculated from the following relationship

$$(-\frac{dE}{dx})_{compound} = \sum_i W_i \left(\frac{dE}{dx}\right)_i \dots \dots \dots (1)$$

The Range is the distance a particle moves in a medium before all its energy is lost.

$$R = \int_0^{E_k} \frac{dE_k}{(dE/dx)} \dots \dots (2)$$

The specific energy curve along the path of the charged charge is called curve Braque. Alpha particles remain on their binary charge in the most of its path, and the loss of specific energy increases roughly as 1/E as predicted by Bethe formula, and the charge is get down near the end of the path by picking up electrons, and observe a curved fall off[8].

3. Results and Discussion

In the Present work the measurements of the mass stopping power and range of alpha particles in the elements of human Bone tissue with energy interval (0.01- 1000) MeV were done using Zeigler's formula and SRIM program. The chemical compositions of human tissues are known to be important in the study of micro diametric distributions in irradiated humans [9]. In addition, alpha-Range in bone tissue was measured using the language of the mat lab, the following shapes illustrate these measurements:
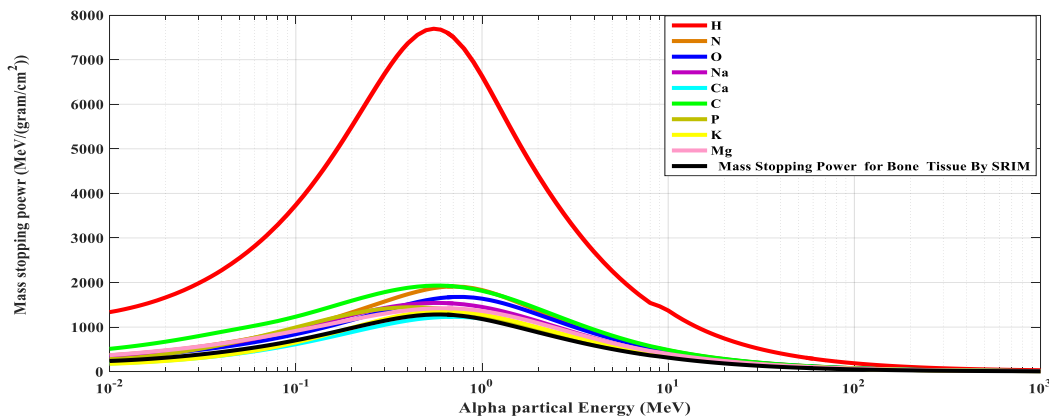

Figure 1: Mass stopping power for alpha particle in the bone tissue by SRIM program.
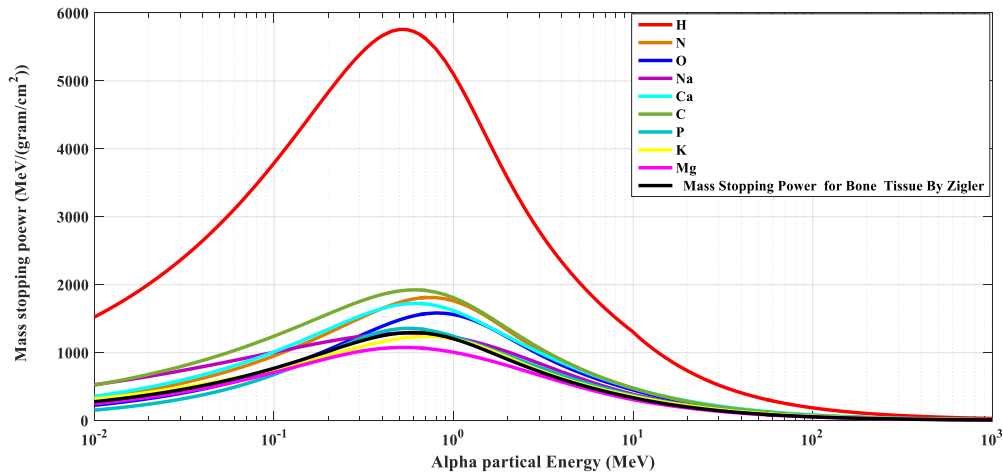
Figure 2: Mass stopping power for alpha particle in the bone tissue by Zigler method.
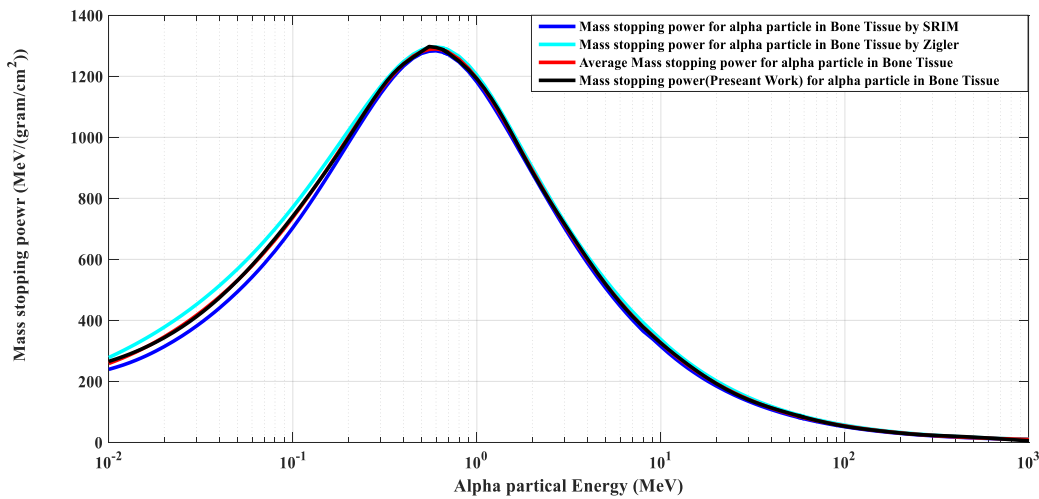

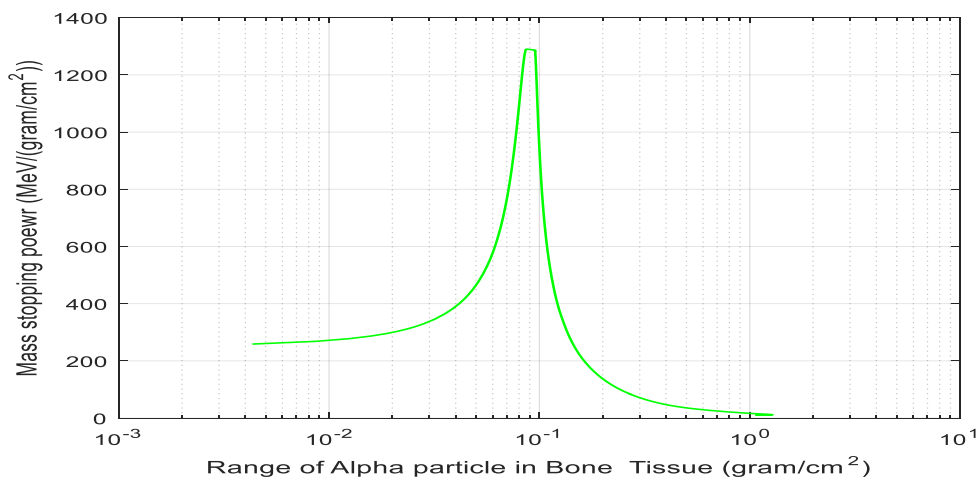Figure 3: Mass stopping power (present work) for alpha particle inthe Bone tissue.

Figure 4: Range of alpha particle in the Bone tissue.

From Figures (1), (2) Note the following

1) At Low Energy: the positively charged particle will then tend to capture electrons from the absorber, which effectively reduce its charge and consequent linear energy loss. At the end of its track, the particle has accumulated z electrons and becomes a neutral atom.[9]. Zeigler's formula and SRIM were successful in that. Whereas the power of stopping increases rapidly in low energies up to the maximum.

2) At high energies, we find that the stopping power is inversely proportional to the square speed of the particle or in other words inversely proportional to the energy of particle. In theory, the reason for the low stopping power at high energies can be explained by the fact that charged particles have high velocity, their survival time near the electron of the target material is reduced and thus the probability of interaction with the electron decreases. As a result, the energy transfer process decreases and this means a decrease in the stopping power. While, at low energies, particle remains next to the electron for a long time, so the probability of interaction with the electron increases, so the transfer of energy increases and the loss of energy increase too [8]. We also find the same behavior in Ziegler's formula and SRIM. Whereas the stopping power gradually decreases with increased energy.

3) The maximum value of mass stopping powers in the same energy as of hydrogen element, due to the hydrogen gas molecules in the path of the passage of alpha particle's ions, thus the more likely the interaction and more energy lost [10]. We conclude that the Hydrogen atoms are most responsible to Energy losing in the human Bone tissue.

2- We obtained the following semi-empirical formula for mass stopping power by calculation of weighted average for stopping power were calculated, compared with two methods:
*Semi-empirical formulas for mass stopping power for alpha particle in the bone tissue.

1-$E \leq 0.6\ MeV$
Linear model Poly6:

$$S.P.(i) = p_1E(i)^6 + p_2E(i)^5 + p_3E(i)^4 + p_4E(i)^3 + p_5E(i)^2 + p_6E(i)\ \ + p_7$$

$p_1 = -3.562 \times 10^{+5}$
$p_2 = 7.139 \times 10^{+5}$
$p_3 = -5.64 \times 10^{+5}$
$p_4 = 2.274 \times 10^{+5}$
$p_5 = -5.371 \times 10^{+4}$
$p_6 = 9223$
$p_7 = 178.5$

2- -$E \geq 0.6\ MeV$

General model Gauss7:
$a_1 = 101.6$
$b_1 = 0.815$
$c_1 = 0.8394$
$a_2 = 1.144 \times 10^{+4}$
$b_2 = -13.51$
$c_{21} = 8.155$
$a_3 = 8.163 \times 10^{+4}$
$b_3 = -95.83$
$c_3 = 42.1$

$a_4 = 1752$
$b_4 = -325.3$
$c_4 = 221.9$
$a_5 = -33.66$
$b_5 = 35.15$
$c_5 = 82.75$
$a_6 = 0$
$b_6 = -218.5$
$c_6 = 2.321$
$a_7 = 28.03$
$b_7 = -93.21$
$c_7 = 846$

$$S.P(i) = a_1\exp(-((x-b_1)/c_1)^2) + a_2\exp(-((x-b_2)/c_2)^2) + a_3\,exp(-((x-b_3)/c_3)^2) + a_4\,exp(-((x-b_4)/c_4)^2) + a_5\,exp(-((x-b_5)/c_5)^2) + a_6\,exp(-((x-b_6)/c_6)^2) + a_7\,exp(-((x-b_7)/c_7)^2)$$

We found that the maximum value of energy the alpha particles can lose along its path in Bone tissue is (1.29×10^3MeV.cm2/gram), which correspond to the energy 0.6MeV.Figure (3) illustrates the stopping power present work.

3- The following semi-empirical equation obtained for Range of particles in Bone tissue.
Semi-empirical equations of range for alpha particles in the bone tissue.*
1-$E \leq 0.6\,MeV$

General model Power2:

$$R(i) = aE(i)^b + c$$

$a = -0.009872$
$b = -0.492$
$$c = 0.09947$$

2 -$E \geq 0.6\,MeV$

Linear model Poly8:

$$R(i) = p_1E(i)^8 + p_2E(i)^7 + p_3E(i)^6 + p_4E(i)^5 + p_5E(i)x^4 + p_6E(i)^3 + p_7E(i)^2 + p_8E(i) + p_9$$
$$p_1 = -1.879 \times 10^{-22}$$
$p_2 = 7.833 \times 10^{-19}$
$p_3 = -1.331 \times 10^{-15}$
$p_4 = 1.185 \times 10^{-12}$
$p_5 = -5.939 \times 10^{-10}$
$p_6 = 1.675 \times 10^{-7}$
$p_7 = -2.616 \times 10^{-5}$
$p_8 = 0.004129$
$$p_9 = 0.09266$$

4– The Bragg Curve: Figure(4) shows a Bragg curve. Through Bragg's curve, we could find the following:

- Near the end of the track, the charge is reduced through electron pickup, and the curve falls off.[8]
- The maximum Range of Alpha particle (0.0868 gram/ cm2) in alpha energy 0.6 MeV

5- Through our findings, we can provide a physician who uses a alpha particles in the treatment to help determine the amount of energy that must be used in the treatment and to determine the exact range in order to reduce the potential damage to cells adjacent to the injured Bone tissue.

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