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Interaction of Alpha Particles with Breast Tissue

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Abstract: ***As modern radiotherapy technology advances, radiation dose and dose distribution have improved significantly. As part of a natural evolution, there has recently been renewed interest in therapy, particularly in the use of heavy charged particles, because these types of radiation 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 Breast Tissue were calculated by using Beth-Bloch equation, Zeigler's formula and SRIM software, also the Range and Liner Energy Transfer (LET) and Breast Thickness As well as Dose and Dose equivalent for this particle were calculated by using Mat lab language for (0.01-200) MeV alpha energy.***

Keywords: Stopping power, Range, Bethe, Ziegler,SRIM, Alpha particle, LET, DoseEquivalent Dose, Effective Dose

1. Introduction

The stopping power is defined as the average energy loss for each unit length path -dE / DEX. It depends upon the charge and speed of incident particles and the target material [1, 2].The strength of the saver, the loss of energy, the range, the dose and the equivalent dose rate of ions into the air, tissues and polymers are very important for many areas of research and application, such as radiation dosimetry, radiation science such as cell leukemia, cellular cell changes, mutation's Radiation, and nuclear physics [3,4].Calculating the stopping capacity is important, this is because they are very important in radiation therapy and possible damage to neighboring tissues, such as breast tissue, which is in the form with a pair located at the highest abdominal area in females, producing milk and feeding infants [5].Chemical composition of breast tissue with fracture weight to each element(H=0.106, C=0.332, N=0.030, O=0.527, Na=0.001, P=0.001,S=0.002 and CL=0.001) [6].

2. Theory

The total stopping power can be obtained from the SRIM-2013 program, which includes rapid calculations that produce tables of stopping powers, and the range and distribution for any ion in any elemental objective [7]. The second way is Bethe Formula, in this formula the rate of energy loss is given by (– dE/dx); being an energy loss, is a negative amount. That there are various forms of the formula, which are essentially the same; it just depends on the way particular authors have wanted to parametric the quantities appearing in the formula [8]. The Bohr formula for alpha particle is given by.

$$-\frac{\mathrm{dE}}{\mathrm{dx}} = \frac{4\pi n Z^2 K_0{}^2 e^4}{m_0 V^2}\left[\ln\frac{2m_0 V}{I}\right] \ldots\ldots\ldots (1)\ [9]$$

Where (z= charge of fallen particle, n= number of electrons per unit volume in the stopping material, m_0= rest mass of electron, V= the velocity of the fallen particle, e= electron charge,$K_0 = 1/4\pi\varepsilon_0$, I= mean excitation energy to the medium and is usually treated as an experimentally). This equation shows that the stopping power depends on. 1-The charge 2- speed of the charged particle 3-The atomic density 4- Charge per atom in the absorber [9]. The other method used in this work to calculate stopping power is Ziegler'sformulae. The energy loss processes are divided up into electronic energy losses and elastic energy losses to the screened nuclei. In this study, we calculated the stopping power using Zeigler's equation at low and high energies were published as the reference [10].

For compound or mixture which consists of thin layers of the pure elements in the right proportion.

$$\left(-\frac{dE}{dX}\right)_{comp} = \sum_i W_i \left(\frac{dE}{dX}\right)_i \ldots\ldots (2) \qquad [11]$$

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

$$R = \int_0^{E_{ki}} \frac{dE_k}{(-dE/dX)} \ldots\ldots (3) \qquad [12]$$

The energy curve specified along the charged particle path is called the Bragg curve. 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 equation, and the charge is reduced near the end of the path by picking up electrons, and observe a curved fall off [13]. LET for heavy charged particles in a way of fundamental importance in radiological physics, dosimetry and radiological biology. The power of the saver and LET are closely related to the dose and with the biological efficacy of different types of radiation.

$$\mathrm{LET} = -\frac{\mathrm{dE}}{\mathrm{dX}} \times \rho \ldots\ldots (4) \qquad [14]$$

The thickness of the substance penetrated by charged particles can be calculated from. $T = \frac{R}{\rho}$ ………. (5) [14]

Where R= The Range, ρ=the material density

Absorbed Dose:A reference to the energy deposited by charged particles per gram of the material. [15]

$$\text{Absorbed Dose} = D = \frac{d\varepsilon}{dm} \ldots\ldots (6) \qquad [16]$$

where $d\varepsilon$ is the average energy imparted to matter in an infinitesimal volume dV at a point of interest in a material of density ρduring a certain period of time by ionizing radiation the dm is mass in the dV

Equivalent Dose the absorbed doses in the tissue or organ because of radiation. [17]

$$H_T = \sum_R W_R \times D \ldots\ldots (16) \qquad [18]$$

WhereW_R = Weighting factor=20 for Alpha particle [19],Weighting factor Represents a conservative judgment of the envelope experimental of particle relevance to be low –level human exposure.

Effective Dose: The weighted for weight of the equivalent dose weight in all tissues and organs specified in the body, given by the expression:

$E = \sum W_T H_T$ .... (17) [20]Where W_T=are committee-defined dimensionless tissue-specific weighting factors= 0.12 for Breast Tissue[19],H_T = Equivalent Dose in Tissue.[18]

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 Breast Tissue with energy interval (0.01- 200) MeV were done using Beth-Bloch equation, Zeigler's formula and SRIM software. The chemical compositions of human tissues are known to be important in the study of micro-diametric distributions in irradiated humans [21] alsomensuration the Range and Liner Energy Transfer (LET) and Breast Thickness As well as Dose and Dose equivalent for this particle were calculated by using Mat lab language. The following figures show these measurements:

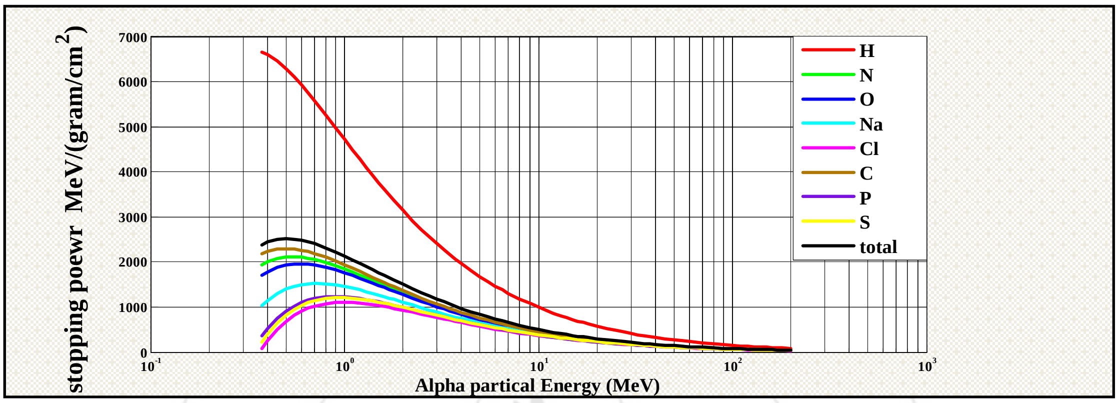

Figure 1: Stopping powers for elements presented in Breast tissue Using Bethe Equation

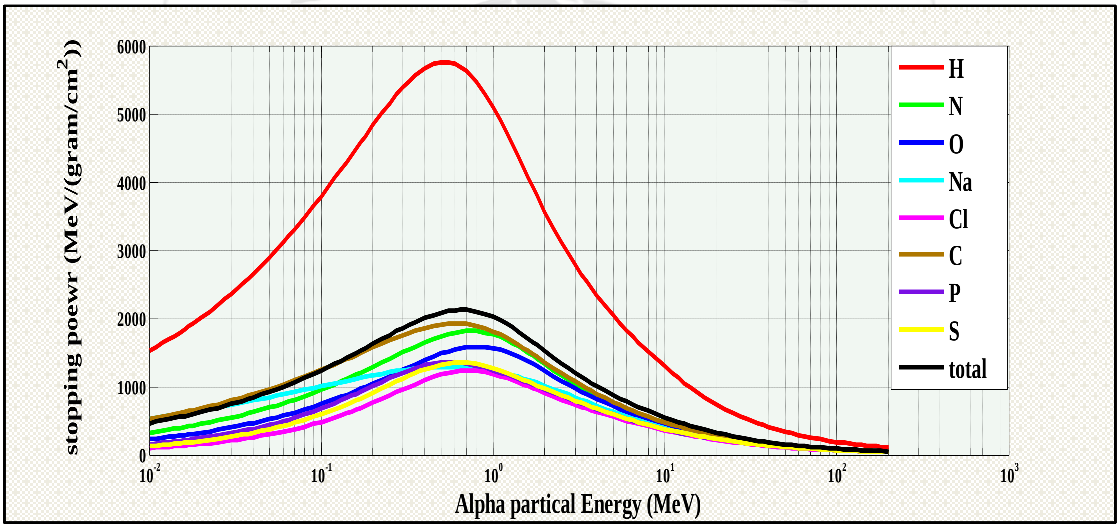

Figure 2: Stopping powers for elements presented in Breast Tissue Using Zeigler's Formula.

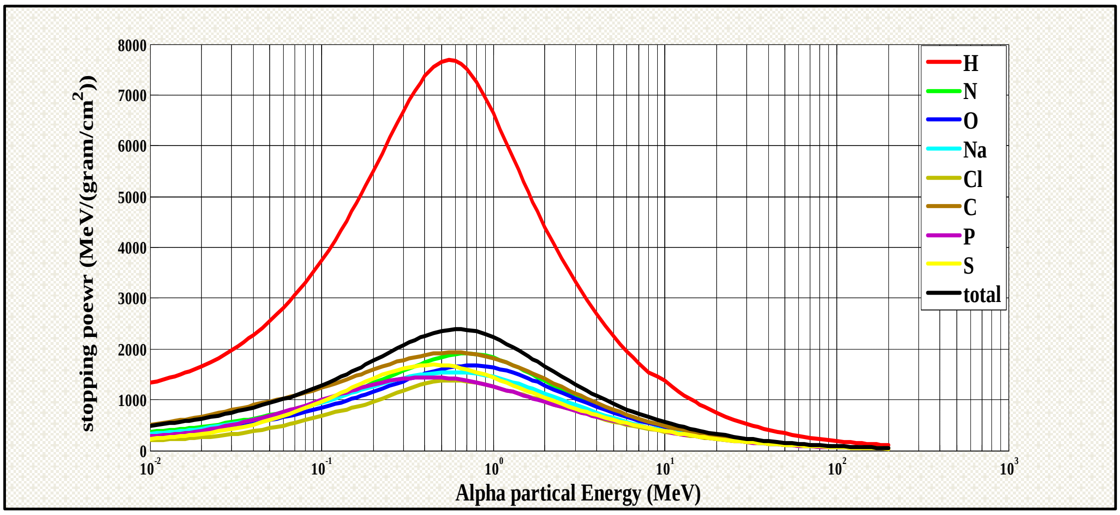

Figure 3: Stopping powers for elements presented in Breast Tissue Using SRIM program

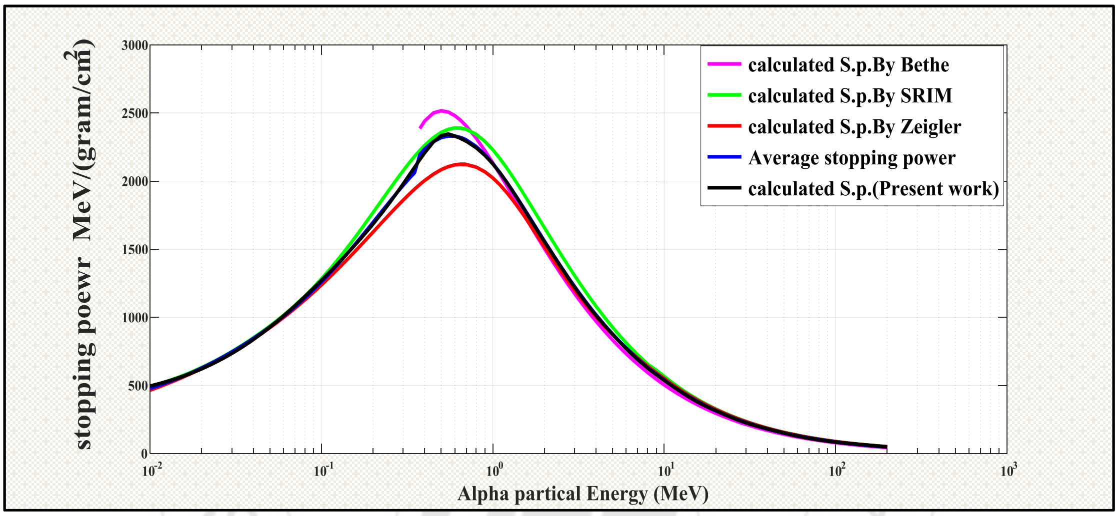

Figure 4: S. P. By Bethe and Zeigler's formula and SRIM program and average S.P. and S.P. (P.W.)

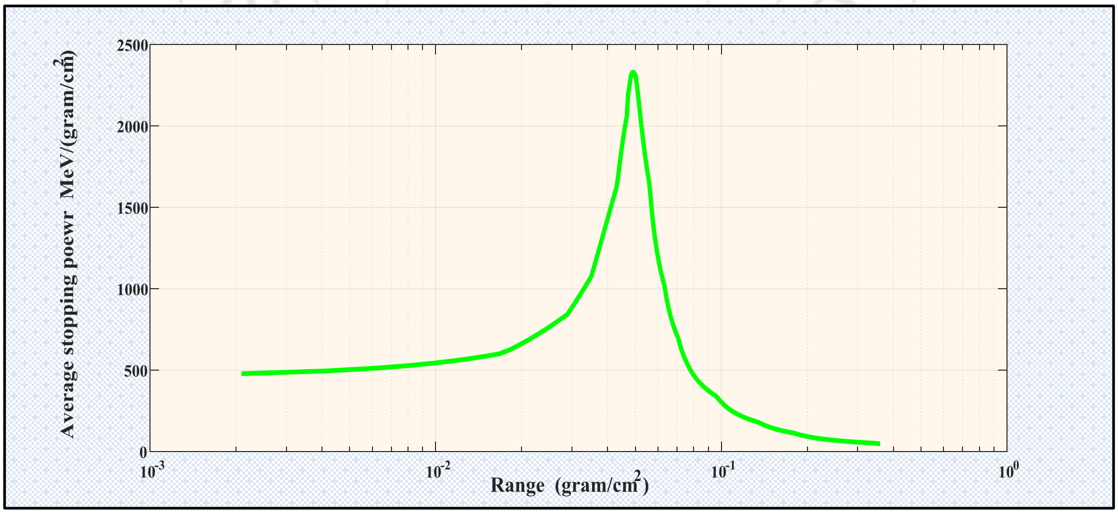

Figure 5: Range as a function averagestopping powerin Breast Tissue

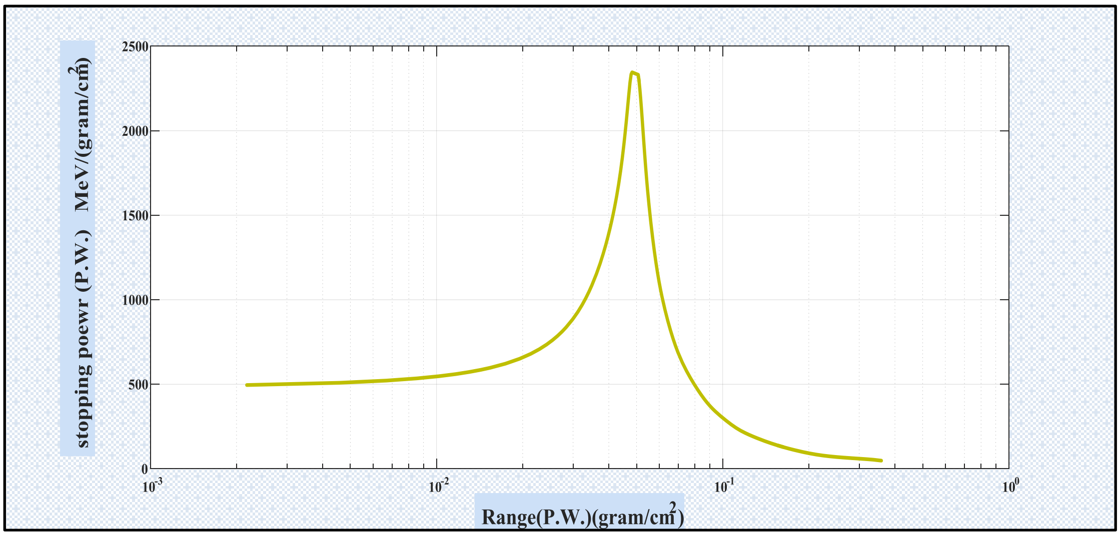

Figure 6: Range as a function stopping power (P.W.) in Breast Tissue

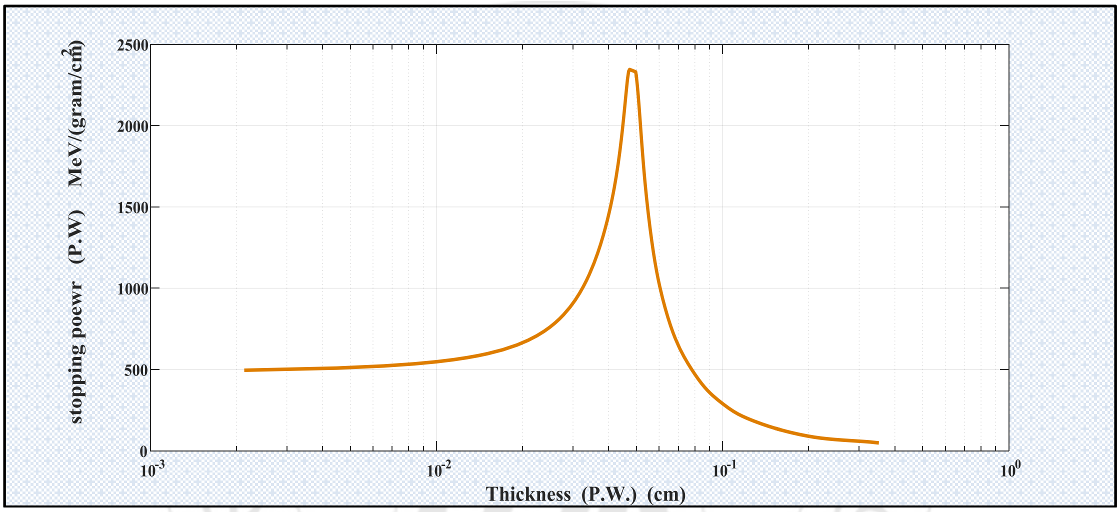

Figure 7: The relationship between Thickness and stopping power (P.W.) in Breast Tissue

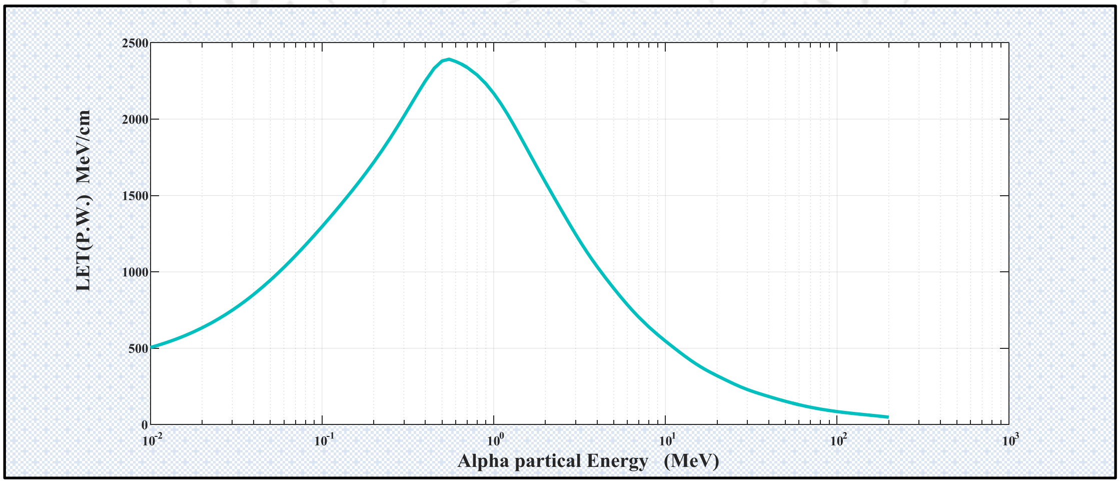

Figure 8: The linear energy transfer (P.W.)as a function E in Breast Tissue

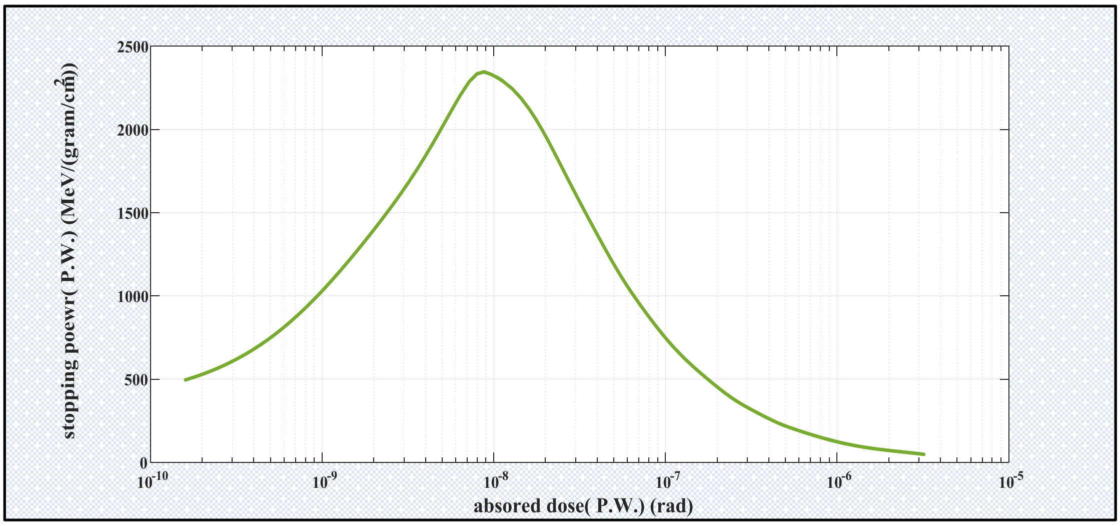

Figure 9: The relationship between S.P. and Dose (P.W.) in Breast Tissue

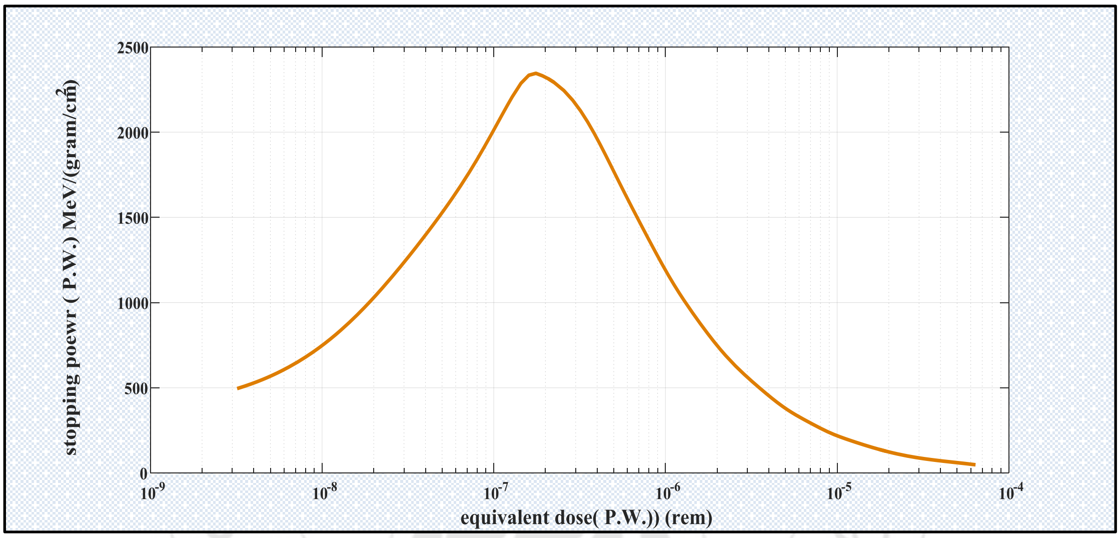

Figure 10: The relationship between S.P. and equivalent dose (P.W.) in Breast Tissue

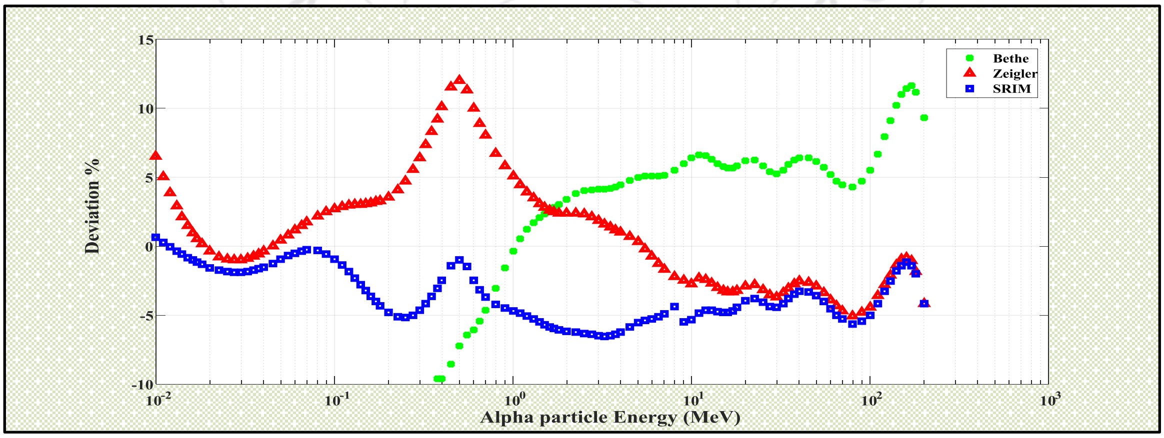

Figure 11: The Percentage deviation of the stopping power values calculated using SRIM2013program and Bethe , Zeigler's Formula as a function of Energy in Breast Tissue for Alpha particles in the Rang (0.01-200)

1- Percentage deviation:The energy behavior of percentage deviation [$\frac{S_{cal} - S_{exp}}{S_{exp}}$]× 100 % between the experimental and the calculated stopping power values using (Bethe and Zeigler Formula and SRIM2013) of Breast Tissue for Alpha particles have energy range of (0.01-200) MeV is shown in Figure (11). It is clearly observed from Figure (11) that the semi-empirical SRIM2013 code produces stopping power values for alpha particle's up-to maximum deficit of 0.6501%and Zeigler Formula produces the values with a deficit of 11.9896%and Bethe Formula produces the values with a deficit of 11.6371%,No any regular trend is observed among the Energy behavior and deviation shown by the values predicted by SRIM2013,and Bethe and Zeigler's Formula, but note the similarity in the behavior of energy and the deviation between the formula of Beth and Zeigler and the correspondence occurs in the energy range $\sim 0.3 - 200$ MeV. We clear that the Zeigler's formula gave much less stopping power values as compared with the present work, but SRIM2013 can give us much better results as compared to the theoretical Bethe and Zeigler.

2- From Figures (1),(2),(3) Note the following:

a) At Low Energy: the Bethe formula begins to fail at low particle's 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.[13] .While Zeigler's formula and SRIM were successful in that. Whereas the power of stopping increases rapidly in low energies up to the maximum.

b) At High Energy: in Bethe, stopping power varies as$1/v^2$, or inversely with particle energy. Theoretically, the reason behind the increase in stopping power can be explained by the fact that charged particles spend more time in close to electron when their speed is low, the impulse felt by the electron, and hence the energy transfer, is largest.[13] .We also find the same behavior in Ziegler's formula and SRIM.Whereas the stopping power gradually decreases with increased energy.

c) 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 [22]. We conclude that the Hydrogen atoms are most responsible to Energy losing in the human Breast Tissue.

3- We obtained the following semi-empirical formula for mass stopping power by calculation of weighted average for stopping power were calculated ,compared with three methods:

$\mathbf{f(E) = p_1E^6 + p_2E^5 + p_3E^4 + p_4E^3 + p_5E^2 + p_6E + p_7}$ **(E < = 0.50MeV)**						
p1= -4.636× 10^5	**p2= 9.178× 10^5**	**p3= -7.588× 10^5**	**p4=3.322× 10^5**	**p5 = -8.409× 10^4**	**p6=1.493× 10^4**	**p7= 354.2**
And $\mathbf{f(E) = a1 * \exp(-((E-b1)/c1).\char`^2) + a2 * \exp(-((E-b2)/c2).\char`^2) + a3 * \exp(-((E-b3)/c3).\char`^2) + a4 * \exp(-((E-b4)/c4).\char`^2) + a5 * \exp(-((E-b5)/c5).\char`^2) + a6 * \exp(-((E-b6)/c6).\char`^2) + a7 * \exp(-((E-b7)/c7).\char`^2)}$ **(E>0.50 MeV)**						
a1 = 464.9	a2 = 351.7	a3 = 1015	a4 = 252.5	a5 = 85.33	a6 = 23.35	a7 = 1.788e+15
b1 = 0.3763	b2 = 0.7928	b3 = -1.558	b4 = 3.941	b5 = -13.53	b6 = 18.48	b7 = -1690
c1 = 0.9041	c2 = 1.657	c3 = 5.187	c4 = 8.789	c5 = 281.2	c6 = 7.54	c7 = 313.1

We found that the maximum value of energy the alpha particles can lose along its path in Breast Tissue is (2.3456×10^3MeV.cm2/gram),which correspond to the Energy 0.55 MeV.Figure (4) illustrates the stopping power present work.

4- The following semi-empirical equationobtained for Range of particles in Breast Tissue.

$f(E) = aE^b + c$ (E <= 0.55)			
a = -0.005996	b = -0.4775	c = 0.05623	
And $f(E) = p_1E^6 + p_2E^5 + p_3E^4 + p_4E^3 + p_5E^2 + p_6E + p_7E + p8$ (E > 0.55)			
p1 =7.96× 10^{-16}	p3 = 1.714× 10^{-10}	p5 = 1.866× 10^{-6}	p7 = 0.003494
p2 = -5.927× 10^{-13}	p4 = -2.451× 10^{-8}	p6 = -8.012× 10^{-5}	p8 = 0.04862

5- The Bragg Curve: Figure (6),(7) shows a Bragg curve.Through Bragg's curve, we could find the following:

a) Near the end of the track, the charge is reduced through electron pickup, and the curve falls off.[13]

b) The maximum Range of Alpha particle (0.0483 gram/cm^2) in alpha energy 0.55MeV

c) The maximum thickness which can alpha particle penetrated it is 0.0473cm were alpha energy 0.55MeV

d) The maximum Liner Energy Transfer the alpha particle that can loss along its path in Brest Tissue is (2.3925×10^3 MeV/cm)at alpha energy 0.55MeV.

e) The Absorbed Doses which corresponds to the Range, thickness is $0.88 \times 10^{-8}\ rad$.

f) The Equivalent Dose 17.6× $10^{-8} rem$,Effective Dose 2.112× 10^{-8} rem at alpha energy 0.55MeV.

We conclude from the points above the following:

1) From figure (6),(7) Note that the Range of alpha particles are roughly equal to the absorbent thickness, this assures that the tracks tend to be completely straight because the particles do not deviate greatly by any single encounter, and interactions occur in all directions simultaneously, Except at their very End.[13]

2) We could to tell the doctor how much alpha energy to use in the treatment and Range it in Breast Tissue and Breast thickness of penetrate and Amount of dose to be given to the patient, in order to achieve the best treatment and less damage to tissues surrounding the tumor.

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