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Interaction of Alpha Practicles with Overy Tissue

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Abstract: Nuclear medicine is important for both diagnosis and treatment. The most common treatment for diseases is radiation therapy used against cancer. The radiation intensity of the treatment is often less than its ability to cause damage, so radiation must be carefully controlled. The interactions of alpha particle with matter were studied and the stopping powers of alpha particle with ovary tissue were calculated using Beth-Bloch equation, Zeigler's formula and SRIM Software also the range and Liner Energy Transfer (LET) and ovary thickness as well as dose and dose equivalent for this particle were calculated by using Matlab language for (0.01-200) MeV alpha energy.

Key words: Stopping power, range, bethe, Ziegler, SRIM, alpha particle, ovary tissue, LET, dose, equivalent dose, effective dose

INTRODUCTION

The main mechanism of the energy loss of heavy charged particle's energy is ionization or excitation of the atoms of matter. The excitation process occurs when the internal energy for the atom increases. The interaction that causes the ionization or excitation process is called the coulomb force which occurs between the fallen particles and the electrons of the material atoms (Poskus, 2015).

To measure the absorbed dose of ionizing radiation in the medium, we need to know: the number of particles or photons or the amount of energy that passing the medium; the amount of energy transferred from the fallen particles to the charged particles of the medium; the rate of energy transfer of charged particles in the middle to the middle itself (stopping power, leading to absorbed dose) (Bailey, 2010).

Calculation of stopping power and absorbed dose are very important in radiation therapy and possible damage to surrounding body tissues. These tissues are ovarian tissue. The ovary is the female reproductive system of vertebrates, located in the side wall of the pelvis. Ovarian function is the production of eggs (Kardong, 2014).

Theory: The total stopping power can be obtained from SRIM-2013 program which includes quick calculations which produce tables of stopping powers, range and 2 straggling distributions for any ion in any elemental target (Ziegler, 1977). The second way is Bethe formula in this formula the rate of energy loss is given by (-dE/dx); being a loss of energy is a negative quantity. That there are various forms of the formula which are essentially the same; it just depends upon the way particular researchers have wanted to parametric the quantities appearing in the formula (El-Ghossain, 2017). The Bohr formula for alpha particle is given by Nigussie (2011):

$$-\frac{dE}{dx}=\frac{4\pi n Z^2 K_0^{\ 2} e^4}{m_0 V^2}[\text{In}\frac{2m_0 V}{I} \quad (1)$$

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 of the medium and is usually treated as an experimentally)

Equation 1 shows that the stopping power depends on: the charge, velocity of the charged particle, the atomic density and charge per atom in the absorber (Nigussie, 2011). The other method used for this research to calculate stopping power is Ziegler formula. 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 (Ziegler, 1977).

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MATERIALS AND METHODS

For compound or mixture which is consisted of thin layers of the pure elements in the right proportion (Leroy and Rancoita, 2009):

$$\left(-\frac{dE}{dx}\right)comp = \sum_i W_i\left(\frac{dE}{dx}\right)i \quad (2)$$

Where:
W_i = Weight fraction
i = The element

The range is simply defined as the distance a particle moves in a medium before all its energy is lost (Bromley, 1985):

$$R=\int_0^{E_{ki}} \frac{dE_k}{(-dE/dX)} \quad (3)$$

The curve of the specific energy along the path of the charged particle 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 (Knoll, 2000). LET for heavy charged particle in a medium is of fundamental importance in radiation physics, dosimetry and radiation biology. Stopping power and LET are closely associated with the dose and with the biological effectiveness of different types of radiation:

$$LET = -\frac{dE}{dX}\times\rho \quad (4)$$

For absorbers that are penetrated by a given charged particle, the thickness can be calculated from:

$$T=\frac{R}{\rho} \quad (5)$$

Where:
R = The range
ρ = The material density

Absorbed dose: A reference to the energy deposited by charged particles per gram of the material (Northwestern University, 2010):

$$\text{Absorbe Dose} = \frac{d\varepsilon}{dm} \quad (6)$$

where, dε is the mean energy imparted to matter in an infinitesimal volume dV at a point of interest of a material of density (ρ) during a certain period of time by ionizing radiation and is the mass in dV (Mattsson and Hoeschen, 2013).

Equivalent dose: The absorbed doses in the tissue or organ because radiation (Piciu, 2012; Mattson and Hoeschen, 2013):

$$H_T = \sum_R W_R \times D \quad (7)$$

Where WR = Weighting factor = 20 for alpha particle (Wrixon, 2008). Weighting factor represents a conservative judgment of the envelope experimental of particle relevance to low level human exposure.

Effective dose: The tissue-weighted sum of the equivalent doses in all specified tissues and organs of the body, given by the expression:

$$E = \sum W_T H_T \quad (8)$$

Where:
W_T = Are committee defined dimensionless tissue-specific weighting factors
H_T = Equivalent dose in tissue (Mattson and Hoeschen, 2013)

RESULTS AND DISCUSSION

In the present work the measurements of the mass stopping power and range of alpha particles in the elements of human ovary tissue with energy interval (0.01-200) MeV were done using Beth-Bloch equation, Zeigler's formula and SRIM Software. It is known that the chemical compositions of human tissues are of importance in studying micro-diametric distributions in human irradiated with radiation (Kim, 1974) also mensuration the range and Liner Energy Transferb (LET) and ovary thickness as well as dose and dose equivalent for this particle were calculated by using MATLAB language. Figure 1-10 show these measurements.

1-Percentage deviation: The energy behavior of percentage deviation $[S_{cal}-S_{exp}/S_{exp}]\times100\%$ between the experimental and the calculated stopping power values using (Bethe and Zeigler formula and SRIM 2013) of ovary tissue for alpha particles have energy range of (0.01-200) MeV is shown in Fig. 11. It is clearly observed from Fig. 11 that the semi-empirical SRIM 2013 code produces

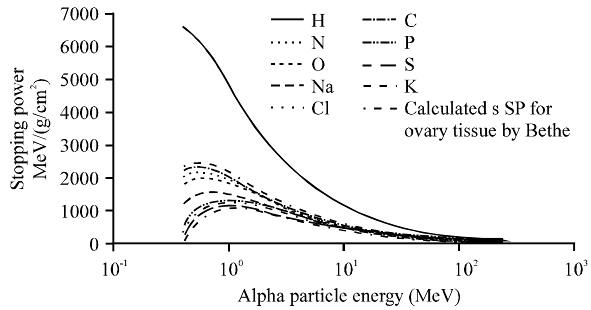

Fig. 1: Stopping powers for elements presented in ovary tissue using Bethe equation

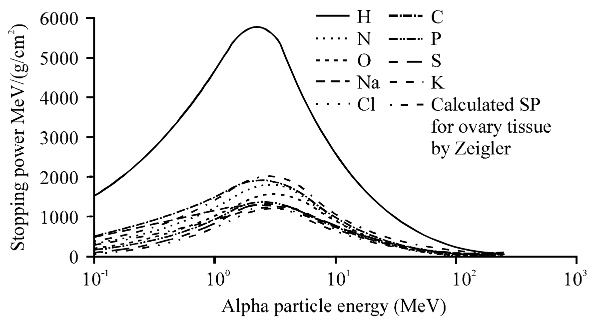

Fig. 2: Stopping powers for elements presented in ovary tissue using Zeigler's formula

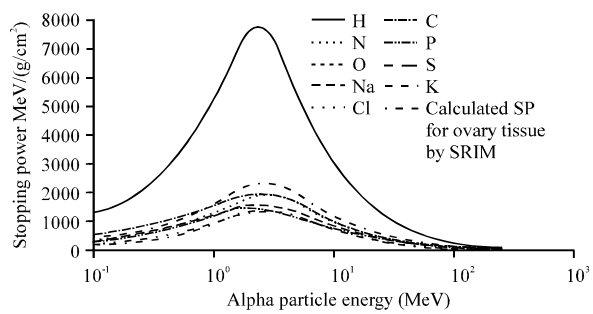

Fig. 3: Stopping powers for elements presented in ovary tissue using SRIM program

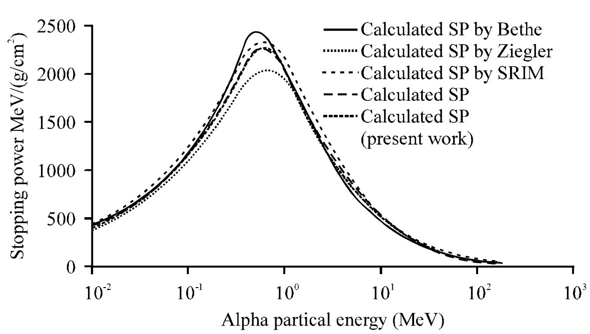

Fig. 4: S.P by Bethe and Zeigler's formula and SRIM program and average SP and SP (PW)

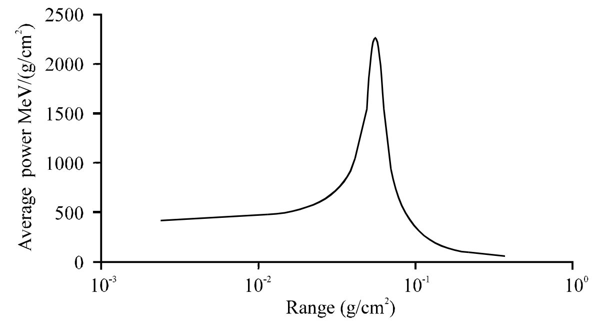

Fig. 5: Range as a function average stopping power in ovary tissue

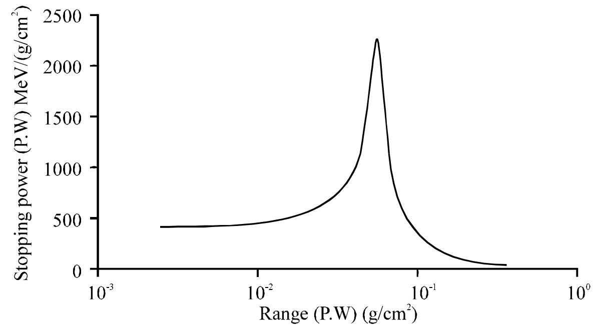

Fig. 6: Range as a function stopping power (PW) in ovary tissue

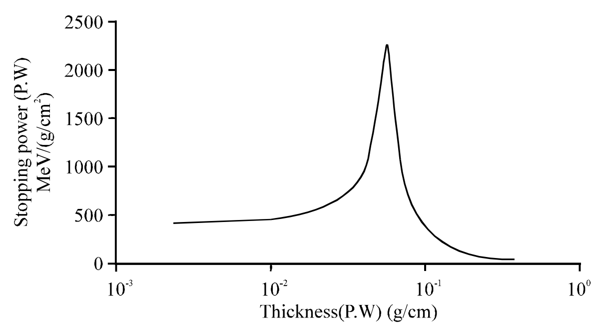

Fig. 7: The relationship between thickness and stopping power (PW) in ovary tissue

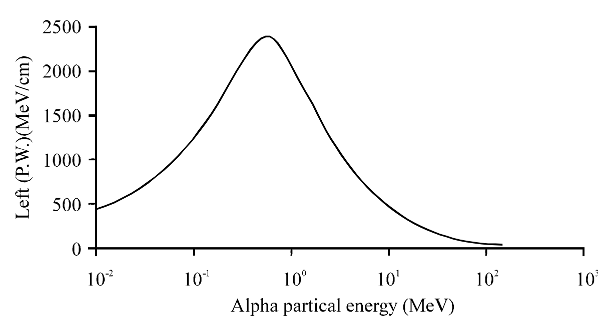

Fig. 8: The linear energy transfer as a function energy (PW) in ovary tissue

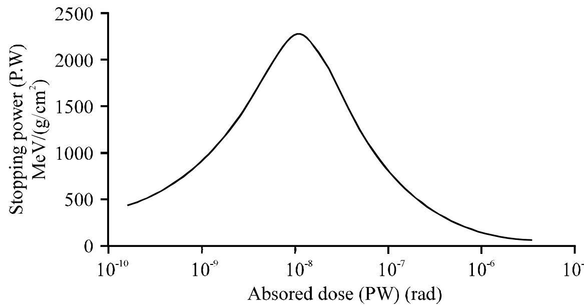

Fig. 9: The relationship between SP and dose (PW) in ovary tissue

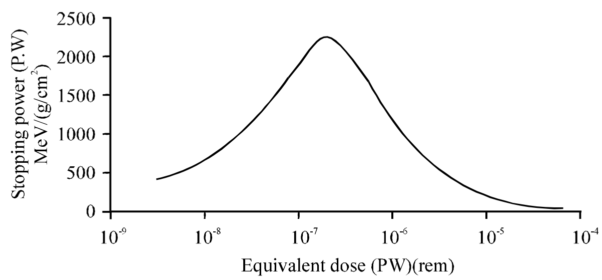

Fig. 10: The relationship between SP and equivalent dose (PW) in ovary tissue

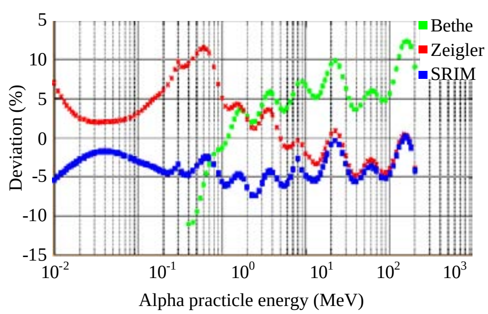

Fig. 11: The percentage deviation of the stopping power values calculated using SRIM 2013 program and Bethe Zeigler formula as a function of energy in ovary tissue for alpha particles in the range (0.01-200) MeV

stopping power values for alpha particles up-to maximum deficit of 0.1590% and Zeigler formula produces the values with a deficit of 11.5444% and Bethe formula produces the values with a deficit of 12.4294%, no any regular trend is observed among the energy behavior and deviation shown by the values predicted by SRIM 2013 and Bethe and Zeigler 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 ~5-200 MeV. We clear that the Zeigler formula give much less stopping power values as compared with the present work but SRIM 2013 can gives us much better results as compared to the theoratical Bethe and Zeigler. From Fig. 1-3 note the following:

At low energy: The Bethe formula begins to fail at low particle's energy. Where charge exchange between the particle and absorber becomes important. 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 (Knoll, 2000). While Zeigler's formula and SRIM were successful in that. As the stopping power increases rapidly at low energies until it reaches the maximum.

At high energy: In Bethe, the 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 the vicinity of an electron when their speed is low, the impulse felt by the electron and hence the energy transfer is largest (Knoll, 2000). We also find the same behavior in Ziegler's formula and SRIM. Whereas, the stopping power decreases gradually with increasing energy.

The maximum value of mass stopping powers at same energy found in hydrogen element because of hydrogen was gas molecules in the traversing path of the alpha particle ions and hence the more probability of interaction and more energy loosed by Devendrappa *et al.* (2015). We conclude that the hydrogen atoms are most responsible to energy losing in the human ovary tissue.

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:

$$f(E) = p_1E^7+p_2E^6+p_3E^5+p_4E^4+p_5E^3+p_6E^2+p_7E+p_8E \leq 0.3$$

- $p_1 = 4.527\times10^7$
- $p_2 = -6.299\times10^7$
- $p_3 = 3.565\times10^7$
- $p_4 = -1.062\times10^7$
- $p_5 = 1.821\times10^6$
- $p_6 = -1.934\times10^5$
- $p_7 = 1.764\times10^4$
- $p_8 = 262$

f(E)a1*exp(-((E-b1)/c1).^2)+a2*exp(-((E-b2)/c2).^2)+
a3*exp(-((E-b3)/c3).^2)+a4*exp(-((E-b4)/c4).^2)+
a5*exp(-((E-b5)/c5).^2)+a6*exp(-((E-b6)/c6).^2)+
a7*exp(-((E-b7)/c7).^2)E<0.3

- a1 = 516.4
- a2 = 659
- a3 = 486.5
- a4 = 402.4
- a5 = 88.53
- a6 = 218.3
- a7 = 215
- b1 = 0.5461
- b2 = 0.9671
- b3 = 1.782
- b4 = 2.283
- b5 = 11.32
- b6 = 5.501
- b7 = -323.9
- c1 = 0.42
- c2 = 0.9837
- c3 = 2.442
- c4 = 7.43
- c5 = 48.32
- c6 = 19.01
- c7 = 427.6

We found that the maximum value of energy the alpha particles can lose along its path in ovary tissue is (2.2618×10^3 MeV.cm^2/g) which correspond to the energy 0.65 MeV. Figure 4 illustrates the stopping power present work. The following semi-empirical equation was obtained for range of particles in ovary tissue:

$$f(E) = a*E^{b}+cE \leq 0.60 \text{ MeV}$$

- a = -0.006064
- b = -0.497
- c = 0.06225

$$f(E) = p_1E^7+p_2E^6+p_3E^5+p_4E^4+p_5E^3+p_6E^2+p_7E+p_8 \quad E>0.6 \text{ MeV}$$

- p_1 = 7.898×10^{-16}
- p_2 = -5.889×10^{-13}
- p_3 = 1.705×10^{-10}
- p_4 = -2.442×10^{-8}
- p_5 = 1.863×10^{-6}
- p_6 = -8.032×10^{-5}
- p_7 = 0.003526
- p_8 = 0.0546

The Bragg curve: Figure 6 and 7 show a Bragg curve. Through Bragg's curve, we could able to find the following:

- Near the end of the track, the charge is reduced through electron pickup and the curve falls off (Knoll, 2000)
- The maximum range of alpha particle (0.0569 g/cm^2) in alpha energy 0.65 MeV
- The maximum thickness which can alpha particle penetrated it is 0.0542 cm were alpha energy 0.65 MeV
- The maximum liner energy transfer the alpha particle that can loss along its path in ovary tissue is (2.3749×10^3 MeV/cm) at alpha energy 0.65 MeV
- The absorbed doses which corresponds to the range and thickness is 1.04×10^{-8} rad at alpha energy 0.65 MeV
- The equivalent dose is 20.8×10^{-8} rem at alpha energy 0.65 MeV

We conclude from the points above the following: Figure 6 and 7 note that the range of alpha particles are roughly equal to the absorbent thickness, this assures that the tracks tend to be quite straight because the particle is not greatly deflected by any one encounter and interactions occur in all directions simultaneously, except at their very end (Knoll, 2000).

We could able to tell the doctor how much alpha energy to use for the treatment and range it in ovary tissue and ovary 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.

CONCLUSION

The merits and demerits of the adopted formulations were given in the present work. These types of calculations will be helpful for the best-known use of radiation for treating disease for radiotherapy which is used against cancer.

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