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Stopping power and Range of Neon ions in ovary tissue in the energies of (1-1000) MeV

قدرة الايقاف والمدى (Ne) في نسيج المبيض في مدى الطاقات(1-1000) MeV لأيونات النيون

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Abstract::
The using of heavy ions in the treatment of cancer tumors allows for accurate radiation of the tumor with minimal collateral damage that may affect the healthy tissue surrounding the infected tissue. For this purpose, the stopping power and the range to which these particles achieved of Neon (Ne) in the ovary tissue were calculated by programs SRIM (The **S**topping and **R**ange of **I**ons in **M**atter), (SRIM Dictionary) [1] ,(CaSP)(**C**onvolution **a**pproximation for **S**wift **P**articles)[2] which are famous programs to calculate stopping power of material and Bethe formula , in the energy range (1 - 1000) MeV .Then the semi - empirical formulas to calculate the stopping power and range of Neon ions in the ovary tissue were founded from fitting for average the values which calculated by using these programs using (MATLAB2016) program, the maximum value of energy for Neon ions can lose along its path in ovary tissue is founded and the range correspond to this value, the maximum range for Neon ions can reached in the ovary tissue is founded too , the importance of research is to know the data of these particles and their use in treatment without causing a bad effect on the patient.
Key Words: Stopping power, Range, Neon ions, Ovary tissue

الخلاصة
استخدام الأيونات الثقيلة في علاج أورام السرطان يسمح بمعالجة دقيقة للورم مع الحد الأدنى من الأضرار الجانبية التي قد تؤثر على الأنسجة السليمة المحيطة بالأنسجة المصابة، لهذا الغرض تم حساب قدرة الايقاف ومدى وصول ايونات النيون في نسيج المبيض بواسطة البرامج (CaSP) و (SRIM) و(SRIM Dictionary) و (Bethe formula) و في نطاق الطاقة MeV (1 - 1000).ثم تم إنشاء صيغة شبه تجريبية بوساطة برنامج (MATLAB2016) لحساب قدرة الايقاف لأيونات النيون في نسيج المبيض وذلك من حساب متوسط القيم باستخدام هذه البرامج ، تم حساب القيمة القصوى لقدرة الايقاف التي عندها يفقد الايون اغلب طاقته وكذلك تم حساب المدى المقابل لهذه الطاقة ، ان أهمية البحث هي معرفة بيانات هذه الجسيمات وكيفية استخدامها في العلاج من حيث الطاقة المطلوبة حسب المدى المحدد للحالة المرضية دون التسبب في تأثيرات جانبية او جرعة عالية قد تؤثر على صحة المريض وتتلف الانسجة السليمه المجاورة للنسيج المصاب.

Introduction:

Of the important quantities that must be known when studying the particles therapy field or interaction of heavy particles with matter is the *Stopping power* and *Range* .The Stopping power is the ability of the medium to stop the particles which penetrate it , the mass stopping power of a material is obtained by dividing the stopping power by the density (ρ). Unit for mass stopping power) is $\mathrm{Mev.cm^2\ g^{-1}}$[3,4], the Range of the particle is the average distance traveled before the particle loses all its original kinetic energy [5]. Which computed by numerical integration of the stopping power. These quantities are studied to determine the energy needed for the particle to penetrate a specific dimension in the tissue. So we select Ne ions which it is used in the particles therapy in some countries of the world including Japan, in the energy range (1-1000)MeV has been chosen because in low energies heavy ions cannot penetrate the materials as the light particles

The interaction of charged particles with materials enters a number of medical fields and nuclear interactions; generally, the interaction of heavy charged particles such as neon (Ne) is different from that of other particles such as protons and alpha particles, which makes it more positive in the treatment of cancer diseases because of the ionic density in the latter orbit, making the damage in the RNA molecule in one cell more effective and this increases the biological efficiency of the dose factor (1.5-3) compared with the use of protons[6].

The aim of this work is to study appropriate database can be chosen by selecting the appropriate energy to irradiate the infected tissue and prevent the passage of these particles into adjacent non-infected tissues, which may cause adverse medical effects on the patient, the interaction of neon ions with ovary tissue, tables (1),(2)Shows the properties of both neon ion and ovarian tissue respectively [18,19].

Table (1) properties of Neon

Name of element	Symbol	Number of protons	Number of neutrons	Number of electrons	Atomic weight (amu)	Electrons configuration	Valency	Atomic density atoms/cm^3 x10^{22}
Neon	Ne	10	10	10	20.18	$[He]2s^2 2p^6$	0	3.593

Table (2) properties of ovarian tissue

Human Tissue	Density g/cm^3	Composition (element: fraction) by weight									
		C	Cl	Fe	H	K	N	Na	O	P	S
Ovary	1.05	0.039	0.002	----	0.105	0.002	0.024	0.002	0.768	0.002	0.002

Thus, the range and stopping power of the ovary tissue of these ions will be studied using several programs which are CaSP, SRIM and SRIM Dictionary and Bethe formula also we calculate the range of this particle. Previous research in this area has been carried out on this ion and carbon such as shown in references [7,8]. In the present work we compared some famous and available theoretical (Casp 5.2)[13] and semi-empirical (SRIM 2008) is a software package concerning the Stopping and Range of Ions in Matter. Since its introduction in 1985, major upgrades are made about every six years. Currently, more than 700 scientific citations are made to SRIM every year [14,15] ,procedures of stopping power calculation has been checked using statistical analysis of deficits between computed and experimental data of (ovary tissue) for (Ne) ions in energy range of (1-1000) MeV .

The range formulas were obtained by directly integrating the reciprocal of stopping power for (Ne) ions and the values of the range for the (ovary tissue) are calculated and compared with (SRIM).

Theory:

*Stopping power:

The Bethe -Bloch formula is used to calculate the stopping power of heavy charged particles derived using relative quantitative mechanics given by the relationship[9,10]:

$$-\frac{dE}{dx}=\frac{4\pi nz^2K_0{}^2e^4}{m_0v^2}[\ln\frac{2m_0v^2}{I}-\ln(1-\frac{v^2}{c^2})-\frac{v^2}{c^2}] \quad \text{--------(1)}$$

Where

(dE/dx):stopping power

Z: charge of the incident particle

n: number of electrons per unit volume.

m_0: rest mass of electron.

V: velocity of incident particle.

e: electron charge.

K_0: 1/4 ЛЄ $_0$

I: mean excitation or the ionization energy of the medium.

This equation shows dependence of (dE/dx) on the velocity of interact particle but($\ln\frac{2m_0v^2}{I}$) almost does not give any little change in (v) . Many researchers have reported a different tables and relationships for stopping power.

For mixture or compound the stopping power can be calculated from the following relation[11]:

$$\frac{dE}{dx}=\sum_i w_i(\frac{dE}{dx})_i \qquad \text{--------(2)}$$

Where W_i:Wight fraction of I the element, (dE/dx):stopping power

*Range of Neon ions:

Because the stopping power depends on the energy of particle, then it is possible to calculate the path of the particle which corresponds to the lower particle energy from the initial valueE_0 to some smaller valueE_1 . Based on the definition of the stopping power, that path is equal to the integral [12]

$$R = \int_{0}^{R} dx = \int_{T_0}^{0} \frac{-dE}{-\frac{dE}{dx}} = \int_{T_1}^{T_0} \frac{dE}{\frac{dE}{dx}} = \int_{T_1}^{T_0} \frac{dE}{\frac{dE}{dx}} + R_1(T_1) \qquad \text{--------(2)}$$

Where dx: path length variable of integration .
(dE/dx): stopping power .
T_0: the initial kinetic energy of the charge particles.
T_1: some limit of energy below the calculation cannot be performed.

Results and discussion:
In the Present work the calculations of the mass stopping power and range of Neon ions in the elements of ovary tissue (C=8.9%,H=10.5%, K=0.2%,N=2.5%,Na=0.2%,O=77.4% ,P= 0.1%andS=0.2%) [14] in energy range (1-1000) MeV have been done using the (SRIM 2008), (Casp 5.2) and (SRIM Dictionary for compound) programs. The results tabulated in table(3) and plotted in figures (1, 2, 3) show these measurements.

1- Using MATLAB 2016 we obtained the following semi-empirical formula for mass stopping power for Neon ions by calculation of the weighted average for mass stopping power.

$$\mathbf{S.P.(P.W)=(p_1.E^5 + p_2.E^4 + p_3.E^3 + p_4.E^2 + p_5.E + p_6)/(E^3 + q_1.E^2 + q_2.E + q_3)}$$

we get the equation constants which are as follows:

p_1 = 0.005046
p_2 = -7.806
p_3 = 3702
p_4 = 5.585e+05
p_5 = -1.335e+06
p_6 = -2.536e+05
q_1 = 17.23
q_2 = 69.84
q_3 = -302.9

Table (3) Mass stopping power for Neon ions interacts with the ovary tissue by using (four methods)

Energy of ion (MeV)	Mass stopping power (MeV.cm^2/gm) for (Neon) in ovary tissue					
	SRIM	SRIM Dic.	CaSP	Bethe formula	Present work	
					average	S.P.(P.W)
1	5639.95	5661.6	3586.821003	63832.77256	4962.790234	4777.758232
2	8576.735	8584.8	5266.336662	86684.5446	7475.957241	7649.0004
3	10968.6	10958.23	6945.852321	79151.51957	9624.228947	9778.136658
4	12754.72	12729.92	8625.36798	70733.27563	11370.00136	11315.66658
5	13999.72	13968.26	10304.88364	63643.38748	12757.62281	12443.7954
6	14842.93	14800.13	10694.8788	57842.15497	13445.98	13263.00861
7	15404.09	15364.11	11084.87396	53062.81277	13951.02517	13849.64763
8	15774.14	15729.46	11474.86912	49071.26986	14326.15564	14260.06179
9	16005.76	15955.76	11864.86428	45690.41992	14608.79377	14536.13278
10	16129.32	16082.73	12254.85944	42789.58982	14822.30234	14709.26554
11	16174.17	16130.21	12286.42884	40271.92812	14863.60135	14803.21321
12	16156.21	16108.06	12317.99824	38064.69679	14860.75525	14836.08675
13	16092.16	16046.23	12349.56764	36112.41818	14829.32035	14821.79748
14	15988.02	15944.63	12381.13704	34372.12337	14771.26226	14771.10254
15	15855.87	15813.22	12412.70644	32810.04511	14693.9311	14692.37012
20	14988.59	14948.16	12570.55344	26890.79305	14169.09975	14064.24331
25	14032.37	13994.99	12050.73192	22931.96942	13359.36443	13301.71009
30	13132.59	13102.81	11530.9104	20078.16854	12588.76961	12553.24932
35	12329.61	12301.21	11011.08888	17912.8631	11880.63744	11863.57744
40	11623.39	11599.978	10491.26735	16207.66024	11238.21261	11241.99835
50	10732.07	10708.213	9451.624313	13682.04335	10297.30215	10187.69126
60	9748.102	9729.001	8896.525779	11891.2221	9457.876313	9338.38831
70	8975.791	8957.114	8341.427245	10548.78024	8758.110841	8642.776992
80	8346.404	8329.436	7786.328711	9501.452812	8154.056275	8062.338587
90	7821.404	7803.9	7350.021227	8659.394802	7658.441693	7569.47163
100	7370.406	7353.464	6913.713742	7966.262869	7400.96164	7144.394766
150	5768.664	5751.115	5451.908245	5760.205588	5682.973174	5643.320102
200	4719.203	4703.41	4458.557095	4565.228007	4611.599424	4689.704589
250	3951.601	3938.974	3859.828779	3808.114509	3889.629689	3998.529513
300	3367.7	3358.676	3261.100463	3282.316342	3317.448306	3459.809547
350	2919.26	2912.459	2928.665879	2894.348527	2913.683284	3022.357317
400	2573.499	2569.294	2596.231295	2595.469655	2583.623369	2659.170381
450	2310.674	2307.164	2382.132292	2357.668444	2339.409603	2354.668811
500	2115.144	2112.058	2168.033289	2163.654951	2139.722469	2099.236911
550	1974.406	1971.9709	2022.912941	2002.155742	1992.861392	1886.619998
600	1880.686	1876.8975	1877.792594	1865.493897	1875.217539	1712.574555
650	1761.642	1758.8347	1768.835707	1748.253673	1759.391577	1574.120317
700	1658.798	1655.7805	1659.87882	1646.50088	1655.239485	1469.1029
800	1488.619	1485.6915	1492.324848	1478.441371	1486.269263	1353.383189
900	1353.488	1351.6214	1358.622687	1345.167416	1352.224871	1356.677805
1000	1243.881	1241.5647	1250.099949	1236.751193	1243.074224	1473.670922

2-The following semi-empirical equation were obtained from same program for Range of Neon ions in ovary tissue:

Range(P.W) = $a.E^{(b+c)}$
we get the equation constants which are as follows:

a = 2.088e-06
b = 1.771
c = 0.002574

3-We note that the maximum value of mass stopping powers found in Hydrogen element, because of Hydrogen was gas molecules in the traversing path of the heavy ions and hence the more probability of interaction and more energy loosed, this conclusion is identical to what is stated in the reference [15].

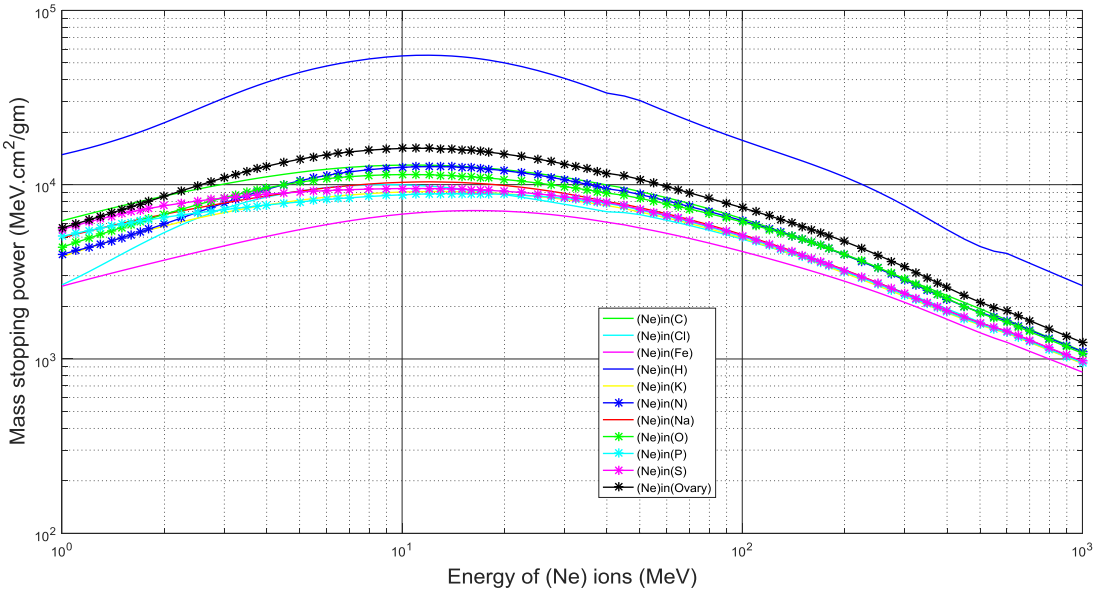
4- From table(3)we found that the maximum value of energy the Neon ions can lose along its path in ovary tissue are (14836.08 MeV.cm^2/g) which correspond to the energy (12 MeV) . Figure (4),illustrates this.

5-We note that the Range correspond to energy which can lose along its path of Neon ions in ovary tissue is (0.00274cm) in energy (12 MeV) . Figure (5), illustrates this.

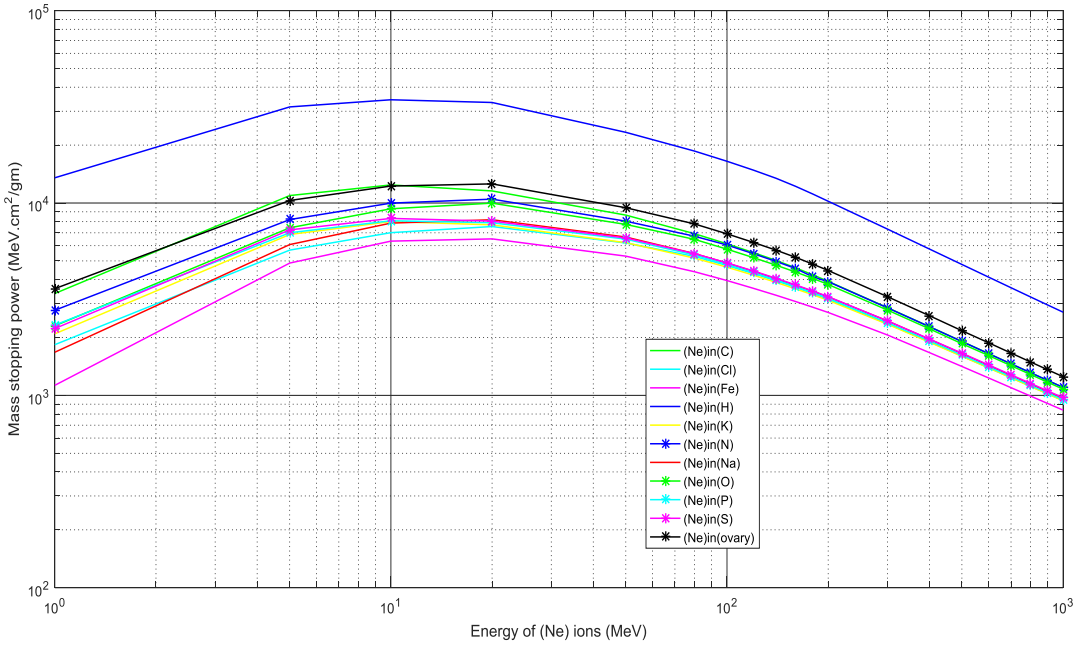
6-From figures (4) note that the theoretical values are consistent with the present work values of the mass stopping power values for Neon ions in ovary tissue indicating the validity of the present results.

7-From figures (5) note that the theoretical values correspond to the present work values of the range for Neon ions in ovary tissue this indicate the validity of the present results.

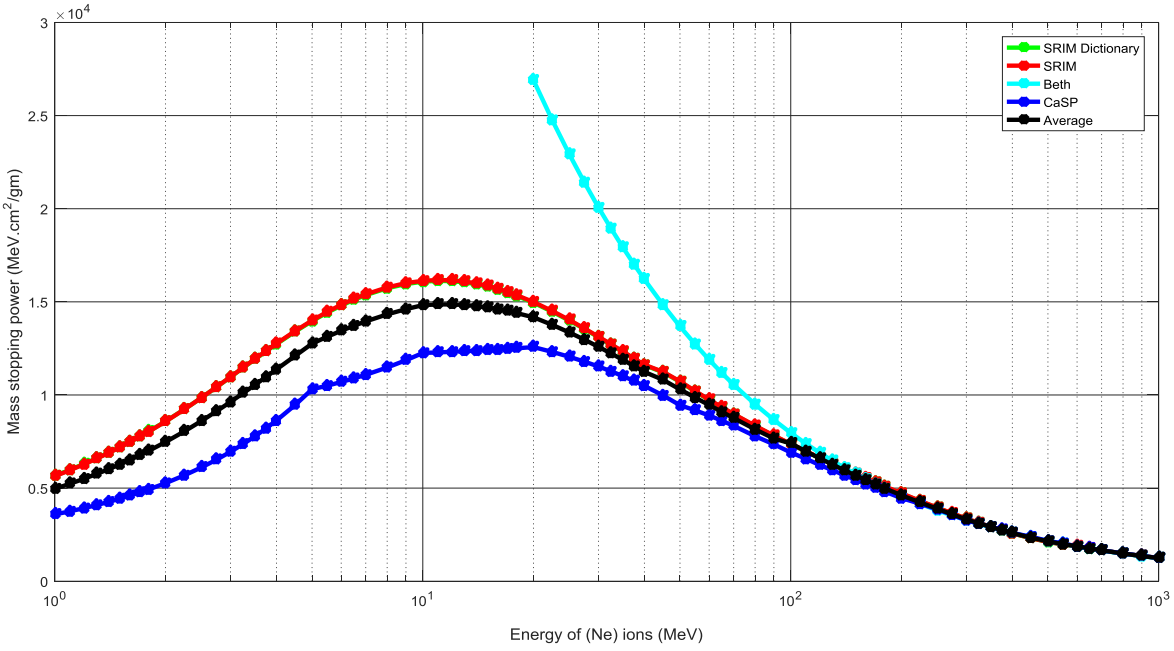
(8) Figure (6) shows the of the Bruuge peak the range to which the neon ions loses most of its energy in ovary tissue.



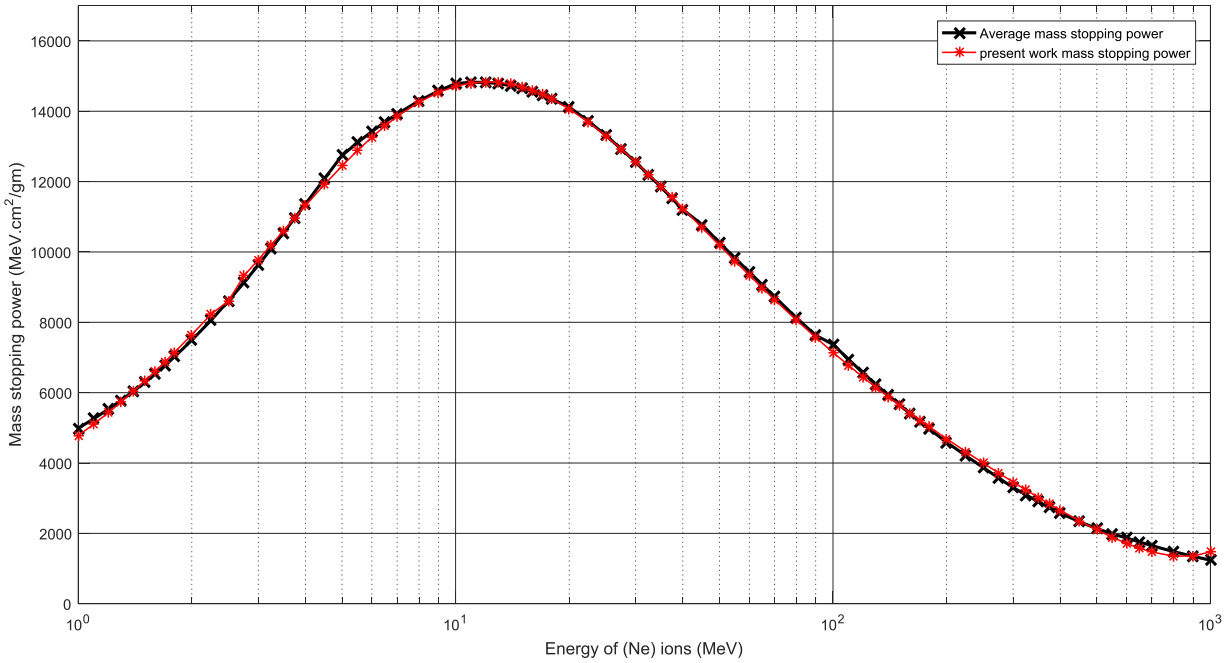
Fig(1): mass stopping power for Neon in (C,Cl,Fe,H,K,N,Na,O,P,S,ovary) by using SRIM program



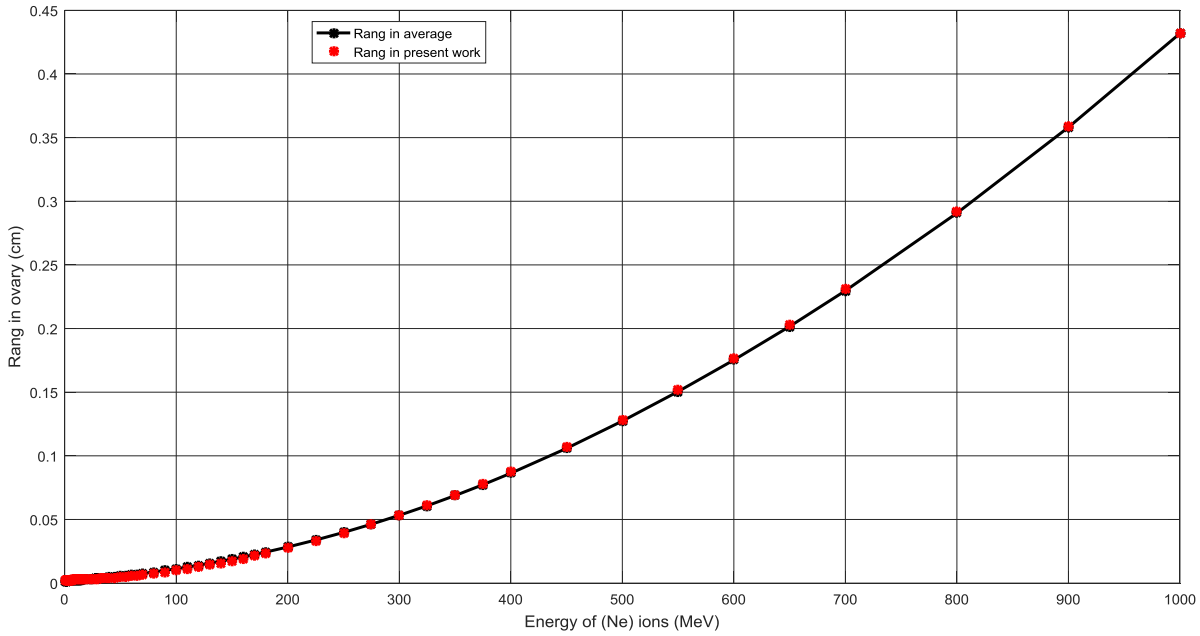
Fig(2): mass stopping power for Neon in (C,Cl,Fe,H,K,N,Na,O,P,S,ovary) by using CaSP program



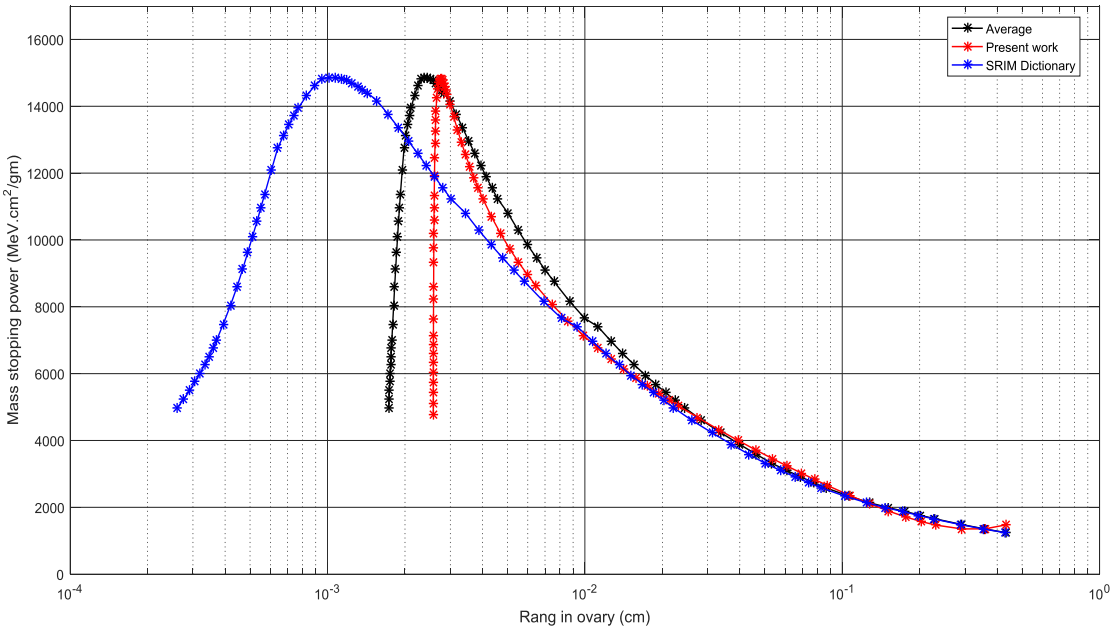
Fig(3): mass stopping power for Neon in ovary tissue (by using SRIM,CASP,SRIM Dictionary programs)



Fig(4): comparison theoretical and empirical mass stopping power of (Ne) ion in ovary tissue



Fig(5): comparison theoretical and empirical Range of (Ne)ion in ovary tissue



Fig(6): Bruuge peak for Neon ions with ovary tissue by (SRIM Dictionary,average of theoretical method and present work)

Conclusions:

The menders can be provided with a database of these ions to enable them to deal with these ions to treat tumors in the ovary, we conclude that the atoms most responsible for loss of energy in the ovary tissue are *Hydrogen* atoms, the maximum value of energy the Neon ions can lose along its path in ovary tissue are (14836.08 MeV.cm^2/g) which correspond to the energy (12 MeV) , the Range correspond to energy which can lose along its path of Neon ion in ovary tissue is (0.00274cm) in energy (12 MeV), Which allows the processor to take into account this energy and the corresponding range of the reach of this particle when used in treatment.

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