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Stopping Powers of Protons in Biological Human Body Substances (Water, Tissue, Muscles and Bones)

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Abstract: **In this work we present a simple relation for calculation of mass stopping power (in MeVcm^2/g) of protons in protons energy range 1-200MeV in some biological human body substances such as Water, Tissue, Muscles and bones. The proposed relations have been described in terms of proton energy only. A good agreements have been found between our simplified values for mass stopping power of protons in Water, Tissue, Muscles and bones and that of Hemalata.**

Keywords: **stopping power, Proton energy.**

1. INTRODUCTION

The stopping power of the matter resulting from the passage of charged particles through it is an important topic not only in the field of physics but also includes large areas of science, it has medical and industrial applications such as the proton radiotherapy as well as their use in space and industry as the manufacture of nuclear detectors for charged particles, and materials intended to protect from different radiations and others important uses[1-5].

Stopping Power is defined as the amount of energy that a particle loses in every unit of length from its path through the materials. Therefore, the process of energy loss of the charged particle passing through the target material must be very accurate through direct practical measurement or through theoretical calculation and study The property of the target material and how it responds to the interaction with the charged particles. The charged particle when it travels through the material is that its interaction with the target atoms is caused by electrostatic forces between the charged particles and that reaction is divided into two elastic collisions with all the atoms and inelastic collisions with the target material electrons. As we Know that the electron Cloud occupies more space than the nuclei of atoms, so the loss of energy caused by the non-elastic collisions are expected to be greater than the loss of energy by elastic collisions.

In this paper, the stopping power of protons in some biological substances in the human body, such as water, Tissue, bones and muscles is calculated using Bethe Equation and the current results will be compared with those calculated by others.

2. THEORY AND CALCULATION METHOD:

The following Bethe stopping power equation [1-3] has been used for energy range 1-200MeV:

$$-\frac{dE}{dx} = \frac{5.08 \times 10^{-31} z^2 n}{\beta^2}[F(\beta) - ln(I)] \qquad (1)$$

Where β is V/c where v is the proton velocity and c is light velocity, I is the excitation energy and F(β) is given by

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$$F(\beta) = ln\frac{1.02\times10^{6}\beta^{2}}{1-\beta^{2}} - \beta^{2}$$

n is calculated using the following relation:

$$n = \frac{N_a \rho Z}{A} \qquad (2)$$

Where Na Avogadro number, ρ is the density of substances and $\frac{Z}{A}$ is the ratio of atomic number to the mass number of substances.

The basic data for biological human body substances are given in Table (1).

The equations for calculated mass stopping power for water, Tissue , Muscules and Bones are given by equations(3-6) respectively based on Bethe equations after substituting the constants from table (1)

For mass stopping power for Water the following equation is used:

$$-\frac{dE}{\rho dx} = \frac{0.170}{\rho\beta^{2}}[F(\beta) - 4.31] \qquad (3)$$

For mass stopping power for Tissue the following equation is used:

$$-\frac{dE}{\rho dx} = \frac{0.172}{\rho\beta^{2}}[F(\beta) - 4.25] \qquad (4)$$

For mass stopping power for Muscles the following equation is used:

$$-\frac{dE}{\rho dx} = \frac{0.177}{\rho\beta^{2}}[F(\beta) - 4.31] \qquad (5)$$

For mass stopping power for Bones the following equation is used:

$$-\frac{dE}{\rho dx} = \frac{0.234}{\rho\beta^{2}}[F(\beta) - 4.45] \qquad (6)$$

3. RESULTS

The results for mass stopping powers for the present work with other researcher are given in Table (2). We have plotted graphs between available mass stopping powers versus protons energy and the mass stopping powers are decreasing with increasing proton energy which are presented in fiq 1-4. Using these data we have been able to find a simple empirical relation for mass stopping power of protons in energy range 1-200MeV by the following relation:

$$Y = a\,X^{b} \qquad (7)$$

Where Y is the mass stopping power, X is the proton energy, a and b are constants, their values are giving in Table (3) for water, Tissue, Muscles and Bones. The present relations are compared with that given by Hemalata [4]:

$$mass\ stopping\ power = Y_0 + A_1 e^{\left(-\frac{x}{t_1}\right)} \qquad (8)$$

Table (1): Basic Data for calculating mass stopping powers

Substances	Density(ρ) g/cm^3	$\langle Z\|A\rangle$	n (Electrons/m^3)	I(eV)
Water	1.000	0.555	3.371×10^{29}	74.6
Tissue	1.020	0.552	3.389×10^{29}	70.3
Muscles	1.050	0.550	3.480×10^{29}	74.6
Bones	1.450	0.527	4.604×10^{29}	85.9

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Table (2): Values 0f mass stopping power (in MeV cm^2/g) of water, Tissue, Muscle and Bones

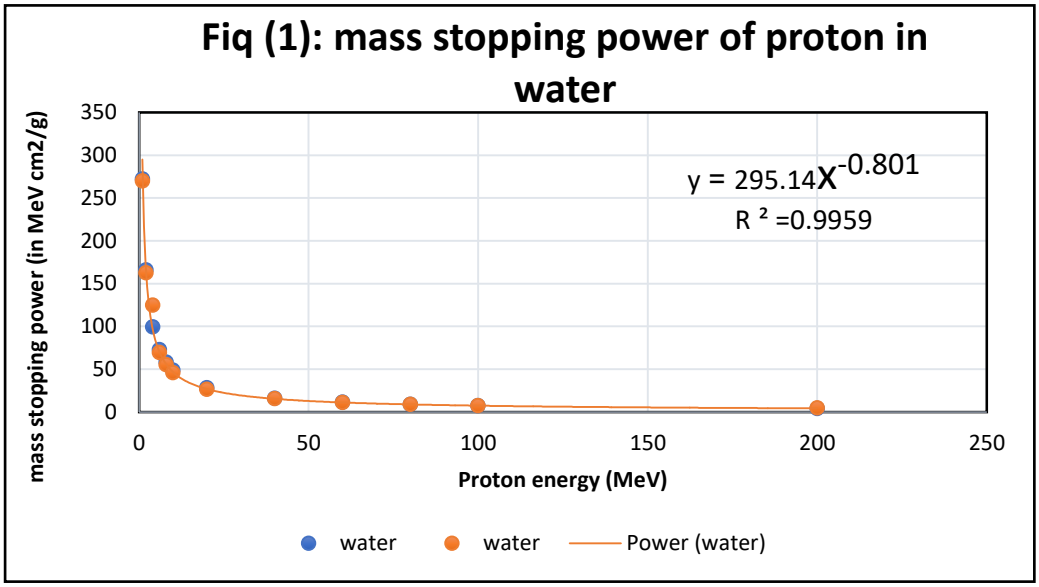
Proton energy (MeV)	water		Tissue		Muscles		Bones	
	This work	Ref (4)	This work	Ref (4)	This work	Ref (4)	This work	Ref (4)
1	269.8	271.99	267.56	276.20	267.00	262.97	245	234.45
2	162.6	165.62	163.78	168.06	162	161.14	148.8	144.93
4	124.58	99.10	95.69	100.48	94.30	97.05	87.58	88.09
6	69.22	72.78	68.73	73.75	67.80	71.54	63.86	65.30
8	54.91	58.23	55.13	59.00	54.40	57.41	50.7	52.1
10	45.86	48.88	46.00	49.51	45.40	48.30	42.4	44.39
20	26.08	28.02	26.14	28.35	25.80	27.88	24.18	25.88
40	15.29	15.75	15.31	15.92	15.2	15.78	14.22	14.80
60	10.77	11.14	10.77	11.25	10.60	11.21	10.02	10.58
80	8.61	8.67	8.62	8.76	8.50	8.76	8.01	8.30
100	7.03	7.12	7.28	7.19	7.10	7.21	6.77	6.86
200	4.49	3.82	4.48	3.85	4.70	3.89	4.17	3.74

Table (3): Values of constants of Equation (7):

Substance	a	b	R^2
Water	295.14	-0.801	0.99959
Tissue	278.26	-0.787	0.9997
Muscles	273.57	-0.784	0.9999
Bones	y=254.1	-0.783	0.9999

Table (4): Values of constants of Equation (8):

Substance	Y_0	A_1	t_1	R^2
Water	0	$3.49705\times 10^8 \mp 3.877 \times 10^7$	$0.03981 \mp 3.14697 \times 10^{-4}$	0.99906
Tissue	0	$3.6275\times 10^8 \mp 4.290 \times 10^7$	$0.03904 \mp 3.29012 \times 10^{-4}$	0.99894
Muscles	0	$2.82992\times 10^8 \mp 3.468 \times 10^7$	$0.0396 \mp 3.50469 \times 10^{-4}$	0.99881
Bones	0	$1.96457 \times 10^8 \mp 3.624 \times 10^7$	$0.03886 \mp 5.2698 \times 10^{-4}$	0.99711



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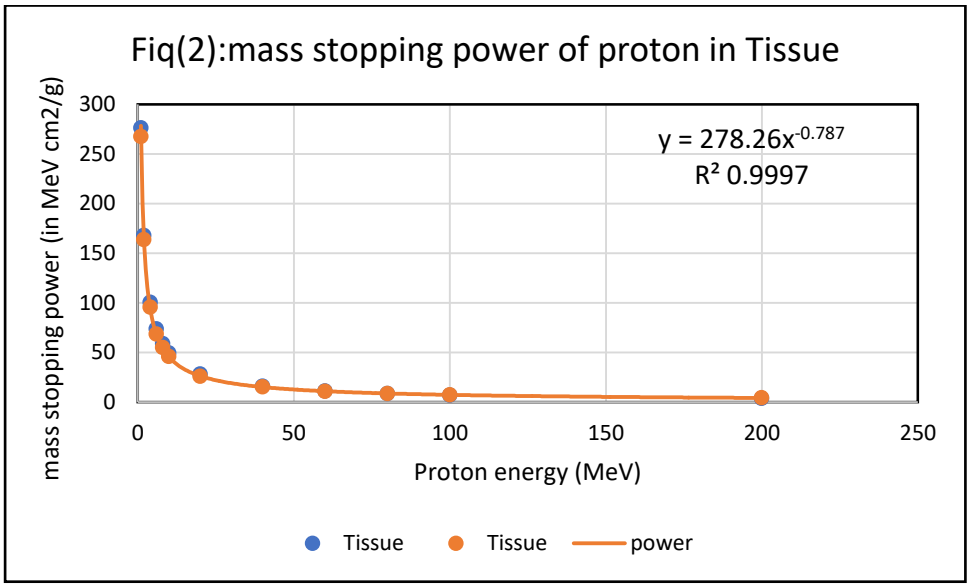

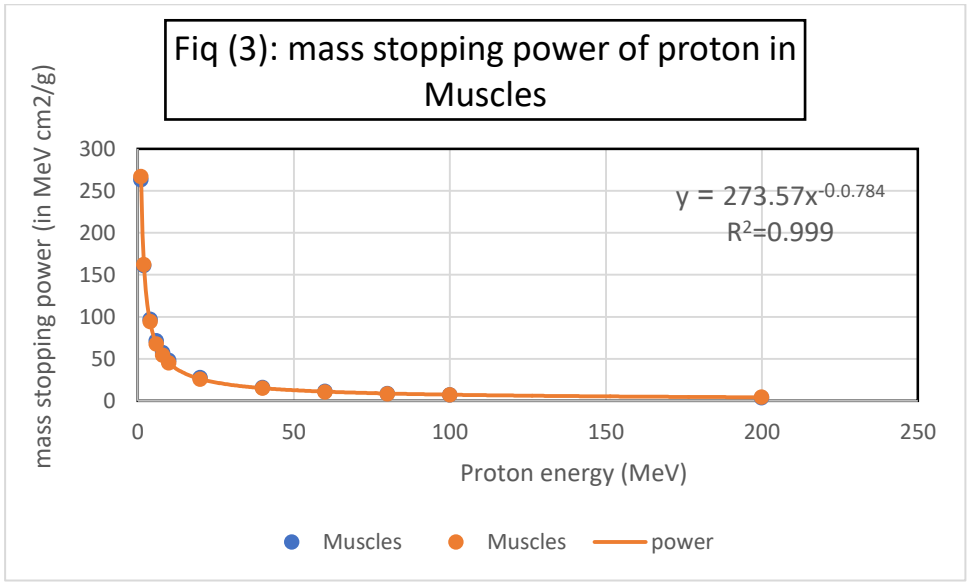

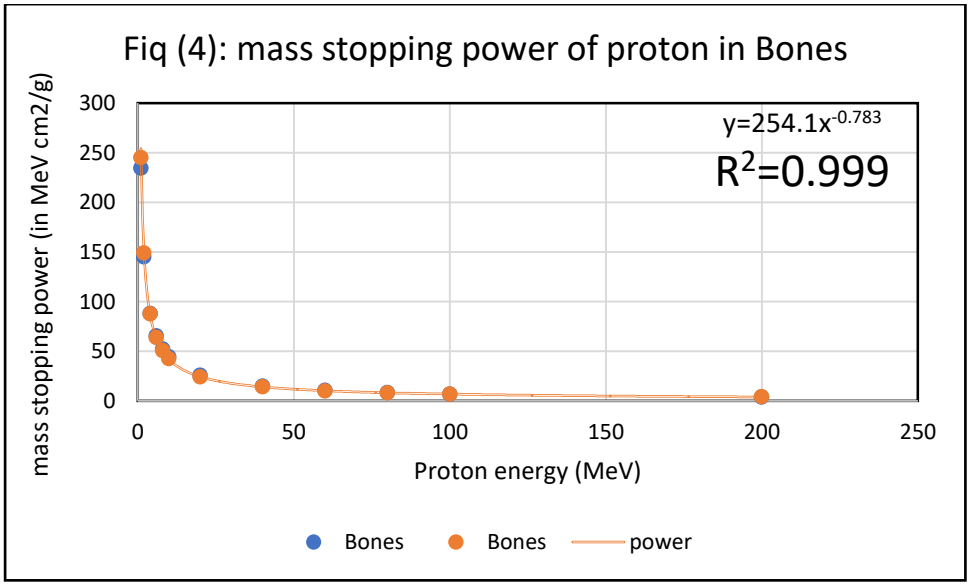

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4. CONCLUSIONS

From the above results obtained using the proposed relations for mass stopping power calculations of proton in some biological human body substances the following conclusions are drown:

1-It observed that the mass stopping power can be expressed in term of proton energy only.

2- It is also noteworthy that the proposed relation is simpler, widely applicable and the values obtained in the present work are in a good agreement with the data proposed by other researcher [4].

3- Also we notice that the mass stopping power decreasing with increasing the proton energy

4- The present proposed equations for mass stopping power are simple and are applied to a large range of proton energy up to 200MeV

5- The equations proposed in the current study give important information for those interested in proton therapy

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