Scholars LITERATURE

La Prensa Medica Argentina

Research Article

DOI: https://doi.org/10.47275/0032-745X-164
Volume 105 Issue 6

Calculation of Stopping Power and Stopping time for Protons in Human Tissues

Kadhim RO[1] and Ali NS[2]*

[1]Faculty of Education for Girls, University of Kufa, Iraq
[2]Faculty of science, University of Karbala, Iraq

Abstract

In this research, the electronic stopping power was calculated using Bethe and Bragg rule equations for the protons in Human tissues (Bone, Muscle (skeletal) and Adipose tissue) all within energy range (0.01-1000) MeV. The equations were programmed using MATLAB 2017; the calculations were compared with the experimental data of the SRIM2013 program and PSTAR code, this comparison showed a good agreement with experimental data.

Keywords: Human tissue; Stopping Power; Heavy particles

***Correspondence to:** Niran S Ali, Faculty of science, University of Karbala, Karbala, Iraq, E-mail: zahramohammed2010@gmail.com

Citation: Kadhim RO, Ali NS (2019) Calculation of Stopping Power and Stopping time for Protons in Human Tissues. Prensa Med Argent, Volume 105:6. 164. DOI: https://doi.org/10.47275/0032-745X-164.

Received: September 25, 2019; **Accepted:** October 09, 2019; **Published:** October 14, 2019

Introduction

The study of the interaction of ionizing radiation (X-rays, electrons, positrons, protons,and heavy ions) with living tissue is of paramount importance in the treatment of cancer because the amount of energy transferred by ionizing radiation to cancer cells will determine the outcome of treatment. Radiation therapy for ions has become common because it can provide High-dose radiation to the target while avoiding adjacent healthy tissues and organs [1].

A charged particle moving rapidly through matter loses energy primarily by ionizing and exciting atoms. An important goal of theoretical understanding of these processes is the prediction of the average rate of energy loss of the particle per unit distance traveled as a function of the particle's energy. This fundamental quantity is called the stopping powerof the material for that particle. It is often denoted by the symbol -dE/d*x* and expressed in the units MeV/cm. Dividing the stopping power by the density ρ of the material gives the closely related mass stopping power,- dE/ρdx, which can be expressed in $\frac{\mathrm{MeV.cm^2}}{\mathrm{g}}$ [2] .

The stopping power is the most important parameter ofthe energy loss process of energetic ions that is passing through matter. The energy loss of heavy ions is complicated because of the charge-exchange effect which leads to charge-state fluctuations [3]. The electronic stopping is caused by the interaction of ions with the target bound electrons [4]. The lost energy of the ions penetrating the material can occur due to several processes excitation and ionization of the target atoms, the capture of the electron, ionization or excitation of the projectile [5]. The aim of this research to study mass stopping power for the protons, in tissues (Bone, Muscle (skeletal), Adipose tissue) using Bethe and Bragg equations.

Theory

Stopping power is defined as loss of energy per distance in the target material which can be written as (-dE/dx) which is depending on the projectile charge and also on the target matter [6]. The study of stopping power is one of the subjects which takes a large space in the study of physics scientists. These studies were theoretical and experimental by using different methods [7]. For compounds Bragg additively, the rule is found to work quite well. The rule says the mass stopping power for the substance containing several elements is taken to be equal to the weighted sum of the mass stopping power of the constituent atoms [8].

$$(-\frac{dE}{\rho dx})_{\mathrm{com}} = \sum_{\mathrm{i}} \omega_i (-\frac{dE}{\rho dx})_{\mathrm{i}} \qquad (1)$$

where:

$$\omega_i = \frac{n_i A_i}{A_{com}}$$

n_i: the number of atoms of the j^{th}kind of atoms in a compound or mixture

ω_i: ratio of the weight of the elements in the compound

A_i: atomic mass of medium

ρ:density of the medium

$(-\frac{dE}{\rho dx})_{\mathrm{com}}$: mass stopping power of compound

$(-\frac{dE}{\rho dx})_{\mathrm{i}}$: mass stopping power for the elements in the compound

Bragg rule is [9]:

$$(-\frac{dE}{\rho dx})_i = \frac{\omega_1}{\rho_1}(-\frac{dE}{\rho dx})_1 + \frac{\omega_1}{\rho_1}(-\frac{dE}{\rho dx})_2 + ... \quad (2)$$

Stopping power of charged particles can be calculated by using Bethe equation (quantum mechanics) [10]:

$$-\frac{dE}{dx} = K\frac{Z_1^2 Z_2}{A\beta^2} L_{Bethe} \quad (3)$$

$$L_{Bethe} = \ln\left[\frac{2m_e c^2 \beta^2}{1-\beta^2}\right] - \beta^2 \ln\langle I\rangle$$

$$K = 4\pi r_e^2 m_e c^2 = 0.307075$$

$$-\frac{dE}{dx} = 0.307075\frac{Z_1^2 Z_2}{A\beta^2} L_{Bethe}(\frac{M_e V.cm^2}{g})$$

$r_e = \frac{e^2}{m_e c^2} = 2.818*10^{-15}$ m classical radius of electron

m_e=9.11*10^{-31} kgrest mass of electron

c=3*10^8m/sec: speed of light in the vacuum

$m_e c^2$=0.511 MeV: The rest mass energy of the electron

Z_1: atomic number of projectiles

Z_2: atomic number of targets

β= $\frac{v}{c}$: relative velocity

⟨I⟩: mean ionization potential of the medium (eV)

Stopping Time

Stopping time is defined as the time required to stop the charged particle in the middle of the sorbent. From extensive experimental studies it was found that we can find the time to stop the charged particles in the sorbent material by the following relationship:

$$\frac{dE}{dt} = (\frac{dE}{\rho dx})(\frac{\rho dx}{dt}) = \rho v(\frac{dE}{\rho dx}) \quad (4)$$

Where $v=\frac{dE}{dt}$ =particle speed

A rough estimate can be made of the time it takes a heavy charged particle to stop in matter, if one assumes that the slowing-down rate is constant. For a particle with kinetic energy, this time is approximately [11].

$$t=\frac{E}{dE/dt} = \frac{E}{\rho v(\frac{dE}{\rho dx})} \quad (5)$$

t: is Stopping time (sec)

Results and Discussion

The equations (1,2,3 and 4) were programmed using MATLAB 2017. The stopping power has been studied, the result demonstrated a good agreement with the present work from the experimental values of SRIM2013 program and PSTAR for protons in the tissues (Bone, Muscle (skeletal) and Adipose tissue) as shown in the figures (Figure 1, Figure 2 and Figure 3).

In energies less than (0.07) MeV where the stopping power is cut off that the reason for these parts attributed to low speed of particle so the stopping number (L_{Bethe}) is negative. The stopping time of protons in some tissues of the human body has been calculated according to equation (5) which was programmed by Matlab 2017 program.

The above figure shows that the stopping time of protons in the studied tissues is almost constant at energies (0.01-0.1) MeV and then starts to increase in a row within the energy (0.1-1000) MeV (Figure 4). That is, the stopping time is increasing within the range of highenergies. The table shows the correlation coefficient (r) of the protons falling on

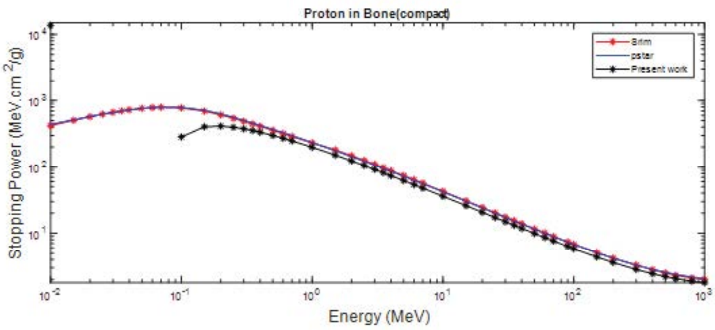

Figure 1: Comparison of the present work, SRIM 2013 and PSTAR for stopping power of bone as a function of projectile energy for protons.

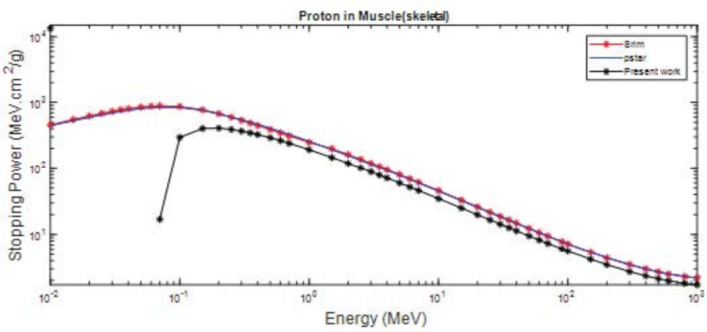

Figure 2: Comparison of the present work, SRIM2013 and PSTAR for stopping power of muscle as a function of projectile energy for protons.

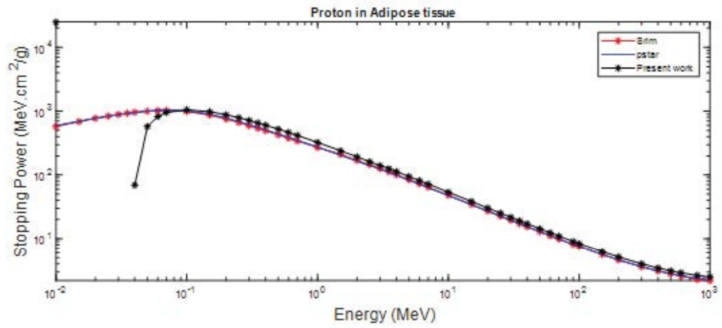

Figure 3: Comparison of the present work, SRIM2013 and PSTAR for stopping power of Adipose tissue as a function of projectile energy for protons.

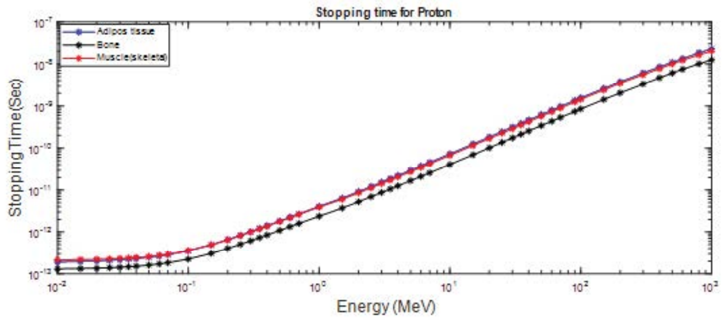

Figure 4: Relationship between the stop time and the energy of the protons falling from the studied tissues.

the studied targets where it is noted that the relationship between the stopping power calculated in this research and the stopping power according to the SRIM2013 program and PSTAR cod for tissues, (Bone, Muscle (skeletal) and Adipose tissuerelevant strong ejection (Table 1).

Table 1: Correlation coefficient values when comparing the electronic stopping power resulting from Bethe equation with SRIM2013 and P-STAR results.

Project	Human Tissue	CORREL
Protons	Bone	0.99
	Muscle(skeletal)	0.95
	Adipose tissue	0.99

Conclusions

- We conclude that the Bethe equation (3) is suitable for the calculation of the electronicstopping power of protons in the studied tissues.
- When calculating the stopping power of protons in studied tissues shows (L_{Bethe}) is negative in energy rang less than (0.07MeV).
- The stopping time is increasing within the energy range (0.1-1000) MeV.
- This research application in several important fields, including the field of studies and scientific research and the field of diagnosis and medical treatment.

References

1. Tubiana M (1990) Radiation interactions with matter: Energy Deposition, Principles of Radiation interactions.
2. Turner JE (2005) Interaction of ionizing radiation with matter. Health Phys 88: 520-544.
3. Yang Q (1994) Partial stopping power and straggling effective charges of heavy ions in condensed matter. Phys Rev A 49: 1089.
4. Giannuzzi LA, Stevie FA (2004) Introduction to focused ion beams: instrumentation, theory, techniques and practice. Springer Science & Business Media, New York, USA.
5. Sigmund P, Schinner A (2001) Binary theory of antiproton stopping. European Phys J D 15: 165-172.
6. Csete A (2002) Experimental investigations of the energy loss of slow protons and antiprotons in matter. CERN thesis 2009: 085.
7. Matare FH (1971) Electronic defects in semiconductors, Wiley-interscience, New York, USA.
8. Getachew A (2007) Stopping power and range of protons of various energies in different materials, Addis Ababa University, Ethiopia.
9. Lozeva R (2005) A new developed calorimeter telescope for identification of relativistic heavy-ion reaction channels, University of Sofia, Bulgaria.
10. Varentsov D (2003) Energy loss dynamics of intense heavy ion beams interacting with dense matter, Technische Universität, Darmstadt, Germany.
11. Turner JE (2008) Atoms, radiation, and radiation protection, John Wiley & Sons, USA.