SSRG International Journal of Applied Physics
ISSN: 2350 – 0301 /doi:10.14445/23500301/ IJAP-V8I1P105

Volume 8 Issue 1, 32-35, Jan-April 2021

Proton Interaction With Water And Human Body Parts Calculations of Range And Stopping Power

M. O. El-Ghossain*

*1 *The Islamic University of Gaza, Physics Department, Gaza, Gaza Strip, Palestine*

Received Date: 05 February 2021
Revised Date: 21 March 2021
Accepted Date: 03 April 2021

Abstract : *Clculations of stopping power (STP), and the Range (R) of protons over the energy range from (10-2MeV to 103 MeV), for different materials; such as water , bone, muscle and tissue and different energies protons have been done; (in MeV cm^2/g), using different programs; STAR and Matlab, the results will be shown for, stopping power vs energy and Range Vs energy with some suitable fitting curves.*

The electronic (collisional) stopping power of the target materials can be calculated by applying the continuous slowing down approximation (CSDA) to calculate the path length (Range). The results of STP is found to be depends on the atomic number Z and the Ionization energy I, and increases rapidly at low energies, reaches a maximum and decreases gradually with increasing energy, the result of the STP and R were fitted to a suitable empirical formula using matlab program as shown in the figures.

Keywords : *Interaction, stopping power (STP), range (R), protons, human body parts, water.*

I. INTRODUCTION - The interaction of protons with different materials and the calculation of the stopping power, energy loss, range, straggling and equivalent dose rate of protons in air, tissue are very important in many research and application fields, such as radiation dosimetry, radiation biology (such as cell, and DNA recombination), radiotherapy and nuclear physics [2-5]. Different techniques have been used for measuring the stopping power of charged particles such as direct energy loss measurement through films, gamma resonance shift measurements, self-supporting method and an indirect verification of the stopping power based on alpha energy losses in air [2-7].
Many experimental and theoretical studies about energy loss, stopping power, range, straggling of ions such as (H, He, Li, C, O) and equivalent dose have been carried in many different human body parts,
In this study the interactions of Protons with matter will be investigated, also we will show the effects of theses interactions with human body, skin, bone, skeletal and different parts of the body.
The main objectives is to calculate the energy loss per distance which is the stopping power and ranges results from the above external and internal radiation interactions with matter, this will leads the evaluations of energy loss and doses which are very important for radiation treatment and the possible damage to adjacent body tissue.
It is well known that the ionization value in tissues is proportional to cells damage. Therefore, the main aim of this study is to evaluate proton energy loss in target organ and in different materials (skin ,water , adipose tissue , muscle skeletal , bone). We use the energy that varies between 10 Kev and 1000 MeV , and calculate the stopping power from the Bethe-Bloch formula as giving in the theory of [1] , for these calculations we will use the Pstar and Mtlab codes [7, 8].
We expect to get results for STP vs energy, and R vs energy for the previous matters and body parts listed above, this study are very important for knowing, Energy loss and dose which are depend with each other and help to formulate the interaction of internal and external radiation with matter to predict the affectivity of the radiation treatment and the possible damage to adjacent body tissue. Radiation treatment is based on different kind of radiation and depends on the different kind of interaction between the radiation and matter (body tissue) [9], the energy loss and dose which human body might exposed during medical treatments or accidents or from natural radioactivity, this will help us in the dose limit and to be more protected, in Gaza we use different kind of radiation in universities, hospitals, knowing the energy loss, dose will help us to protect ourselves and our environment.

II. Stopping Power of Protons

Stopping power of a medium can be defined as the average unit of energy loss suffered by the charge particles per unit path length in the medium under consideration.[1, 2]
Stopping power is mainly collision. The first is the most important, resulting from the collision interaction between the incident particles and atomic electrons. Mass collision stopping power is widely used to reduce the dependence on the medium density (ρ) [2]. The total stopping power can be obtained from SRIM-2003 program [15], which calculates the stopping power and range of ions

(10eV-2GeV/amu) in matter using a quantum mechanical treatment of ion-atom collision (the manual of SRIM refers to the moving atom as an "ion", and all target atoms as "atom").

The energy loss in matter has been calculated by many physicists, but the basic, classic derivation was due to Bloch who improved a calculation by Bethe; hence the Bethe-Bloch Formula.

The rate of energy loss is given by (– dE/dx); which being a loss of energy, is a negative quantity. The calculation of dE /dx is done in such a way as to determine the energy deposited in the medium (positive) where the explicit negative sign for the loss of energy of the particle [4].

The full expression for the Bethe-Bloch formula can be written as:

$$-\frac{dE}{dx}=\left(\frac{e^2}{4\pi\varepsilon_0}\right)^2\frac{4\pi z^2 N_A Z\rho}{mc^2\beta^2 A}\left[\ln\left(\frac{2mc^2\beta^2}{I}\right)-\ln(1-\beta^2)-\beta^2\right] \qquad (1.1)$$

The quantity -dE/dx is known as the STOPPING POWER and is denoted as STP.

The range is simply defined as the distance a particle moves in a medium before all its energy is lost. This can be determined from the stopping power provided we know the the form of S from zero energy up to the initial energy of the particles in the incident beam

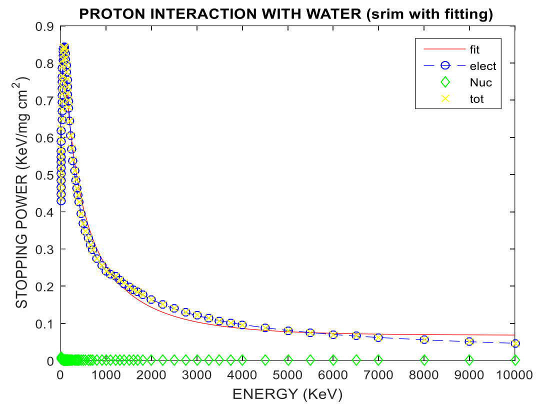
The range can be determined as given below:

$$\text{Range (approx.)} \quad R=\int dx=\int_E^0 \frac{dE}{dE/dx} \qquad (1.2)$$

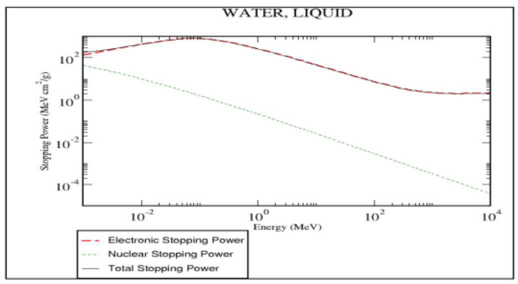
Where the integration from 0 to maximum distance. We can use the Bethe-Bloch formulism to calculate the stopping power for protons.

III. Calculations of Stopping Power of Protons

The STP calculation for protons traversing matter is similar to that for heavy charged particles. The interaction of incident protons with atomic electrons, leading to excitation and ionization, can be calculated from Bethe's theory, and it is called the "Collisional Stopping Power". The results are shown in figures 1, 2, 3, 4, and 5 with fitting using matlab program.



Figure(1):Stopping power of Proton in water by srim



Figure(2): stopping power of Proton in water, by by pstar

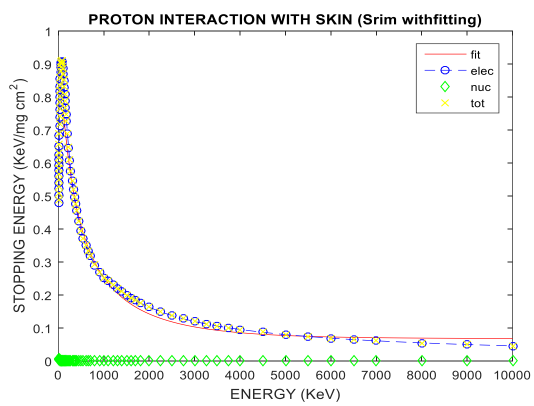


Figure (3): Stopping power of protons in skin

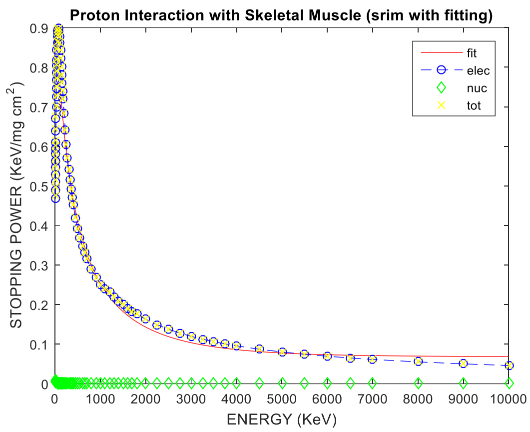


Figure (4): Stopping power of (H) with Skeletal Muscle

Stopping power of (H) with Bone:

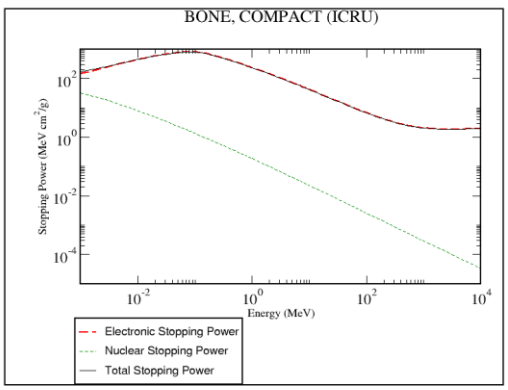
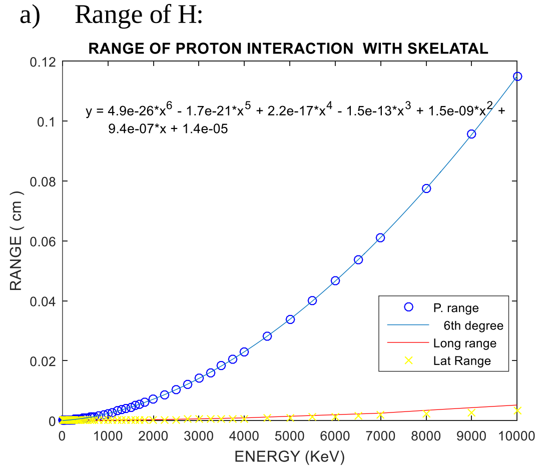
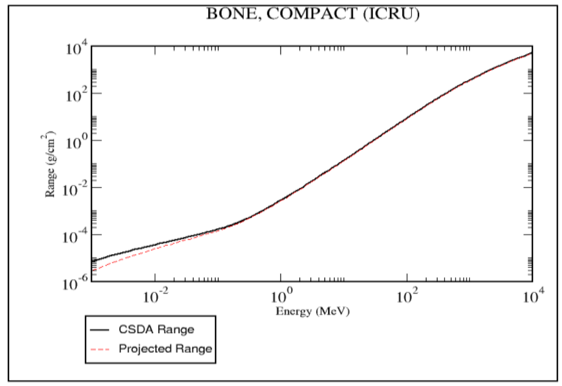


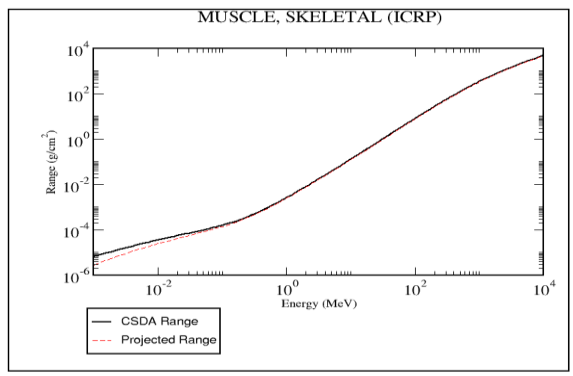
Figure (5) Stopping power of Hydrogen in Bone

a) Range of H:

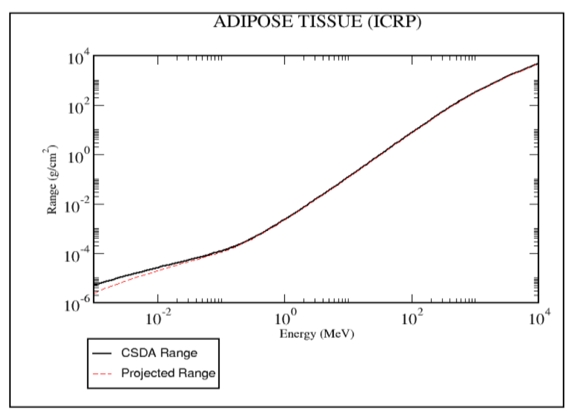




Figure(6): Range of H in bone



Figure(7) : Range of H in muscle



Figure(8): Range of H in Adiapose Tissue

IV. Calculation of the Range of Proton and Fitting

The range of a charged particle is the distance it travels before coming to rest. The range is NOT equal to the energy divided by the stopping power. Like mass stopping power, the range in g cm-2 applies to all materials of similar atomic composition [11, 12, 13, 14, 15, 16].

The figures 6, 7, and 8 show the range of protons in different materials including human body parts. Fitting equations have been tried for the range; it was found that the fifth degree and sixth degree fit very well as shown in the figures [10,11, 12,].

Conclusion

It is well known that the ionization value in tissues is proportional to cells damage. Therefore, the main aim of this study is to evaluate proton energy deposition in target organ and in various entrance layers (skin, water, dipose tissue, musle, skeletal, ,bone). We used the energy that varies between 10KeV and 1000MeV , and obtained the STP diagram for each energy beam .

1)The total STP is proportional to atomic number and ionization energy.

2)STP total increases rapidly at low energies reaches a maximum and decreases gradually with increasing energy.

3)The Range of the protons is calculated from STP in the absorber material.

4) The STP depends on the energy loss only little energy loss is shown, but the energy loss maximizes when particles have slowed down to energies which correspond with the peak of the energy loss curve.

For high initial energies the coefficients are large which translates into a maximum of energy loss at smaller depths which decreases gradually with the decrease of the absorption coefficient towards lower energies.

Stopping power of protons in the energy range from 0.01Mev to 1000Mev for a number of elements . For low Z substances , STP is almost constant between 0.5 Mev and several Mev .The rise of the curves at low energies is due to increasing of collisions probability .

Body tissue is typically low Z material and the range can be approximated. The different fitting equations have been tried for different material ranges, the fifth and sixth degree fit very well with the coefficients shown on the graphs.

References

[1] Kenneths.Krane , Introductory Nuclear Physics ,Oregon stat University, (1987).

[2] R. Macian, Biological Effects of Radiation ,Reactors Concepts Manual, USNRC Technical Training Center

[3] National Research Council, Committee on the Biological Effects of Ionizing Radiation, Health Effects of Exposure to Low Levels of Ionizing Radiation, BEIR V, National Academy Press, Washington, D.C.,(1990).

[4] Fred A. Mettler, Jr., M.D. and Arthur C. Upton, M.D. Medical Effects of Ionizing Radiation, Grune & Stratton, Inc., Orlando, Florida, (1995).

[5] World Health Organization,Ionizing radiation ,health effects and protective measures, http://www.who.int/mediacentre/factsheets/fs371/en (2012).

[6] A.Markowicz, Rene Van Grieken , Handbook of X-Ray Spectrometry, Second Edition

[7] W. Brandt, and M. Kitagawa, Effective stopping-power charges of swift ions in condensed matter, Phys. Rev. B25 (9)(1982) 5631-5637,.

[8] L.E. Porter, Further observations of projectile-z dependence in target parameters of modified Bethe–Bloch theory., Int. J. Quantum Chem. 95(4-5)(2003) 504-511.

[9] P.M. Echenique, R.M. Nieminen, J.C. Ashley, and R. Ritchie., Nonlinear stopping power of an electron gas for slow ions, Phys. Rev. A33(2)(1986) 897-904,.

[10] J. F. Ziegler, Nucl. Instr. Meth. B (2004) 219-220, 1027.

[11] J. F. Ziegler, SRIM – the stopping and range of ions in matter, http://www.srim.org (2009).

[12] A. Jablonski, C. J. Powell, and S. Tanuma, Surf. Interface Anal. 37(2005) 861.

[13] A. Jablonski, Prog. Surf. Sci. 79(2005) 3.

[14] A. Jablonski, F. Salvat, and C. J. Powell, J. Phys. Chem. Ref. Data 33(2004) 409.

[15] F. Salvat, A. Jablonski, and C. J. Powell, Comput. Phys. Commun. 165(2005) 157.

[16] http://physics.nist.gov/cgi-bin/Star/ap_table.