International Journal of Scientific Research in Physics and Applied Sciences **Research Paper**
Vol.6, Issue.6, pp.116-121, December (2018) **E-ISSN:** 2348-3423

Effective Atomic Number, Electron Density and CT Numbers of Skeletal Muscle Relaxants for Imaging

Suresh K C[1], *Sathish KN*[2]

[1]Government College for women, Maddur-571428, Karnataka, India
[2]Government First Grade College, Chikkaballapur, Karnataka, India

Corresponding author email: kunigalsuresh@gmail.com

Available online at: www.isroset.org

Received: 08/Dec/2018, Accepted: 26/Dec/2018, Online: 31/Dec/2018

Abstract- The Effective atomic numbers Z_{eff} , Electron density N_e and CT numbers of skeletal muscle relaxants tubocurarine chloride, gallamine triethiodide, pancuronium bromide, suxamethonium bromide and mephenesin for total and coherent, incoherent, photoelectric absorption, pair production in atomic and nuclear field photon interaction have been calculated in the wide region 1keV to 100GeV. The molecular, atomic, electronic cross sections are calculated using mass attenuation coefficient of relaxants obtained by running WinXCOM programme and finally Z_{eff}, N_e and CT number of the relaxants have been estimated. The Z_{eff}, and N_e have found to vary with energy and composition of the relaxants and this variation is shown graphically for all photon interaction. Even CT numbers are also not remaining constant with energy. The significance of CT number in visualizing the image of the biological samples is discussed particularly in the low energy region as this region is extensively used in the medical radiology. This helps in cross-sectional image of internal organs in the field of medicine for diagnosing the diseases. The CT number is not only outlining the inhomogeneities of the tissues but also give the direct information of the tissue electron density from which accurate corrections can be made by suitable treatments.

Keywords; Effective atomic number, Electron density, CT number, relaxants

I. INTRODUCTION:

Cross-sectional image of internal organs is prime importance in the field of medicine for diagnosing the diseases. Computed tomography (CT) measures the accurate radiographic density of the small parts of the body which helps in visualizing the image. The CT number is not only outlining the inhomogeneities of the tissues but also give the direct information of the tissue electron density from which accurate corrections can be made by suitable treatments. Even dose calculations are made based on the patient specific information obtained from X-ray computed tomography.

In the present study skeletal muscle relaxants tubocurarine chloride, gallamine triethiodide, pancuronium bromide, suxamethonium bromide and mephenesin have chosen and its composition is given in the table 1 These agents are used as adjuvant to anesthesia to get the relaxation of skeletal muscle during the corrections of dislocations, surgery, radiotherapy etc… and used as relieving painful muscle spasms because of various musculoskeletal and neuromuscular disorders. Hence accurate calculation of photon mass attenuation co-efficient, effective atomic number Z_{eff}, electron density N_e and CT numbers of above relaxants are important in medical diagnostics. Especially calculation of CT numbers of relaxants is become prime important as it provide the necessary information about relative electron density of relaxants. The contribution of these values will find the application in planning and treatment of the patient in radiotherapy. Hence the above parameters become vital, interesting and exciting field of research for characterization and visualization of matter (biological samples) in medical field.

Table-1 Composition of skeletal muscle relaxants

Skeletal muscle relaxants	Composition
Gallamine triethiodide	H:0.067834 C:0.404167 N:0.047132 O:0.053838 I:0.427030
Mephenesin	H: 0.077441 C: 0.659151 O:0.26340
Pancuronium bromide	H:0.082541 C:0.573763 N:0.038234 O:0.087347 Br:

	0.218114
Suxamethonium chloride	H: 0.086249 C: 0.423200 N: 0.070503 O: 0.241598 Cl: 0.178451
Tubocurarine chloride	H:0.067916 C: 0.575857 N: 0.036299 O: 0.228050 Cl: 0.091878

II. THEORY AND METHODOLOGY:

When electromagnetic radiation passes through matter, their intensity is attenuated according to the exponential law. If a beam of these radiations having an intensity I_0 passes through a thickness x of an absorber, the transmitted intensity I is given as

$$I = I_0 \exp\left(-\mu/\rho\right)x$$

where ρ is the density of the material.

(μ/ρ) is the mass attenuation coefficient & is independent of density of the absorber.

When a beam of photons passes through an absorber, the photons interact with the atoms and are either absorbed (photoelectric effect, pair and triplet production, photo nuclear) or scattered away from the beam (Coherent and incoherent scattering). The intensity of the transmitted beam of photons is the sum of the cross-sections, per atom for all the above processes. Hence the total molecular cross section σ_{mol} is determined from the following equation using the values of mass attenuation coefficient of relaxants using $(\mu/\rho)_{bio}$ obtained by running WinXCOM programme.

$$\sigma_{mol} = \left(\frac{1}{N}\right)\left(\frac{\mu}{\rho}\right)_{bio}\sum_i n_i A_i$$

Where N is Avogadro number, n_i is the number of atoms of i^{th} element and A_i is its atomic weight in a given molecule.
The effective atomic cross section σ_{atm} are determined by

$$\sigma_{atm} = \frac{\left(\mu/\rho\right)_{bio}}{N\sum_i W_i A_i}$$

$$\sigma_{atm} = \frac{1}{N}\sum_i f_i A_i\left(\frac{\mu}{\rho}\right)_i$$

Where f_i is the fractional abundance $(\mu/\rho)_i$ is mass attenuation co-efficient of i^{th} element.

$$\sigma_{atm} = \frac{\sigma_{mol}}{\sum_i n_i}$$

The effective electronic cross section σ_{ele} are determined by

$$\sigma_{ele} = \left(\frac{1}{N}\right)\sum_i\left\{\left(\frac{f_i A_i}{Z_i}\right)\left(\frac{\mu}{\rho}\right)_i\right\}$$

Where, and Z_i is the atomic number of i^{th} element in a molecule respectively.
Then effective atomic number is calculated using

$$Z_{eff} = \frac{\sigma_{atm}}{\sigma_{eie}}$$

The effective electron density is obtained from

$$N_e = \frac{N}{\sum_i n_i A_i} Z_{eff}\sum_i n_i$$

The CT number is estimated from

$$CT = \frac{\left(\mu_m - \mu_w\right)}{\mu_w}$$

III. RESULTS AND DISCUSSIONS:

The Z_{eff} and N_e and CT numbers of skeletal muscle relaxants tubocurarine chloride, gallamine triethiodide, pancuronium bromide, suxamethonium bromide and mephenesin are determined in the energy region 1keV-100GeV. It is found that Z_{eff} and N_e of relaxants vary with energy and composition of them. This variation is shown in the figures1-12 for total and all partial photon interaction (Coherent, Incoherent, Photoelectric absorption, pair production in atomic and nuclear field).

Total photon interaction:

The variation of Z_{eff} with photon energy for total photon interactions is as shown in the figure 1 and this variation is because of dominance of different photon interactions with skeletal muscle relaxants. In lower energy region, photo electric interaction dominates, hence Z_{eff} varies similar to photo interaction. Except mephenesin, all other relaxants Z_{eff} increases and becomes maximum and decreases sharply in the energy region 0.002-025MeV.This variation are due to presence of halogens (Cl, Br and I) in their composition and these elemental cross sections varies larger in the energy region 0.002-025MeV.The Z_{eff} and found to remain constant up to 10MeV which shows that scattering (coherent and Incoherent) processes increases. From 10MeV to100MeV, there is regular increase in the Z_{eff} with photon energy. This is due to the increase in incoherent and pair production processes. From 100MeV onwards Z_{eff} remains constant which is due to dominance in pair production processes. The Z_{eff} values of relaxants vary from the element with lowest Z to the highest Z present in their composition.

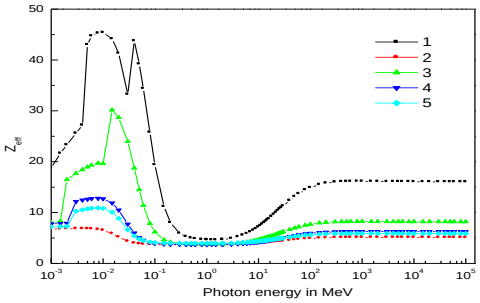

Fig: 1 Variation of Z_{eff} with Photon energy E in MeV for total photon interaction (with coherent) (1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide (4) Suxamethonium chloride (5) Tubocurarine chloride

The variation of N_e with photon energy of all relaxants for total photon interaction processes is similar to that of Z_{eff} and is as shown in the figure 2

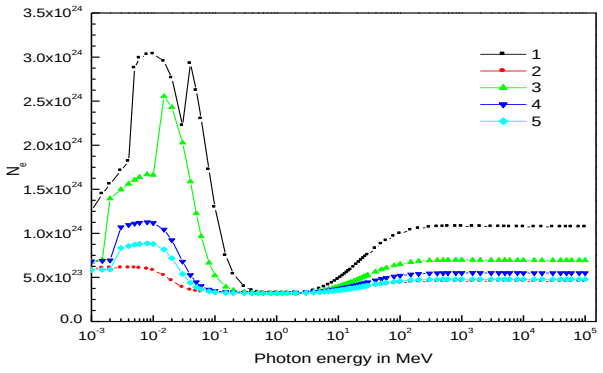

Fig: 2 Variation of N_e with Photon energy E in MeV for total photon interaction (with coherent) (1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide (4) Suxamethonium chloride (5) Tubocurarine chloride

Photo electric absorption:

The variation of Z_{eff} with photon energy for photo electric absorption interaction is as shown in the figure 3 and this indicates that Z_{eff} increases up to 0.040MeV for all relaxants except for mephenesin which is independent of photon energy. In case of Gallamine triethiodide there is sudden increase in Z_{eff} at 0.033169MeV which is the K absorption edge of iodine and it remains constant with photon energy. In Pancuronium bromide sudden increase in Z_{eff} is found at 0.01347MeV which is the K absorption edge of bromine and it remains constant with photon energy. The Z_{eff} of Suxamethonium chloride and Tubocurarine chloride increases at 0.002822MeV because chlorine (K absorption edge of Cl is 2.8224keV).Thereafter it becomes constant with increase in photon energy. This is due to the dominance in photoelectric processes in low energy region i.e. less than 1MeV and for the substances of higher atomic number (Z) than for low Z substances.

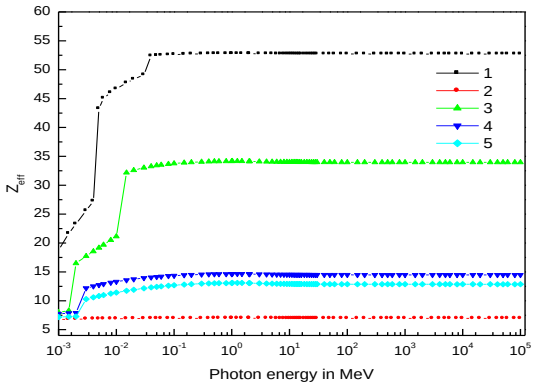

Fig: 3 Variation of Z_{eff} with Photon energy E in MeV for photoelectric absorption (1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide (4) Suxamethonium chloride (5) Tubocurarine chloride

The variation of N_e with photon energy of all relaxants for photoelectric absorption processes is similar to that of Z_{eff} and is as shown in the figure 4

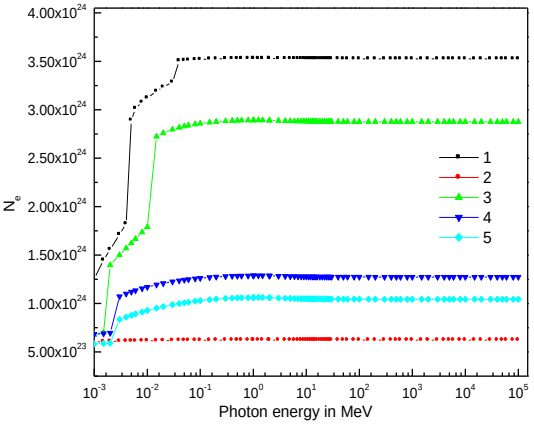

Fig: 4 Variation of N_e with Photon energy E in MeV for photo-electric absorption (1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide(4) Suxamethonium chloride (5) Tubocurarine chloride

Incoherent scattering:

The variation of Z_{eff} with photon energy for incoherent scattering is as shown in the figure 5 and it indicates that Z_{eff} increases from0.001MeV to 0.10MeV shows that it depends on energy. This variation is because of the proportion and the range of atomic numbers of the elements present in

relaxants. Above 0.10MeV Z_{eff} remains constant and independent of energy for all relaxants.

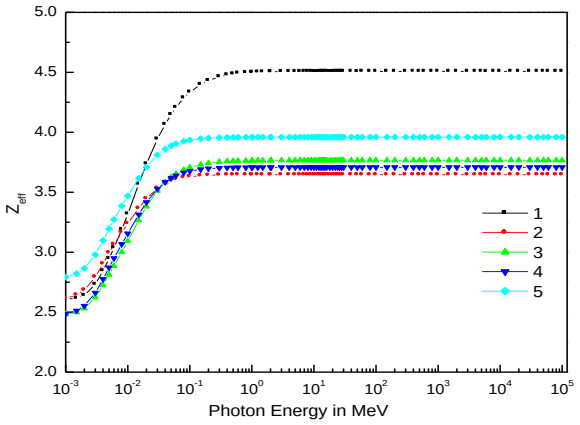

Fig: 5 Variation of Z_{eff} with Photon energy E in MeV for incoherent scattering
(1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide
(4) Suxamethonium chloride (5) Tubocurarine chloride

The variation of N_e with photon energy of all relaxants for incoherent scattering processes is similar to that of Z_{eff} and is as shown in the figure 6

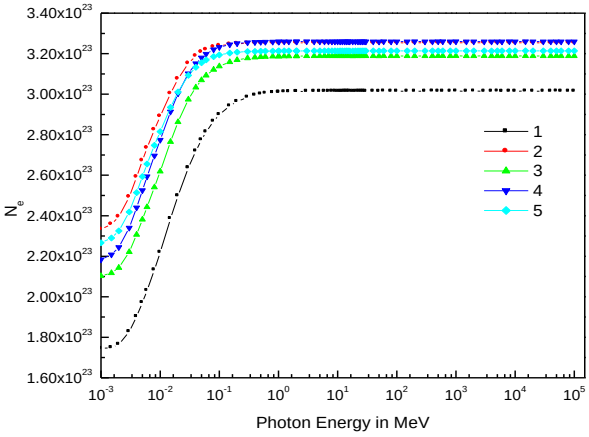

Fig: 6 Variation of N_e with Photon energy E in MeV for incoherent scattering
(1)Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide
(4) Suxamethonium chloride (5) Tubocurarine chloride

Coherent scattering:

The variation of Z_{eff} with photon energy for coherent scattering is as shown in the figure 7 and it indicates that Z_{eff} increases for mephenesin up to 0.03MeV and remains constant.All other relaxants shows increment in Z_{eff} from 0.001MeV to 0.40MeV. Thereafter remains constant i.e. independent of energy. The values of Z_{eff} for gallamine triethiodide, pancuronium bromide, suxamethonium chloride and tubocurarine chloride have comparatively higher.This is due to the presence of halogens. (42.70% of I in gallamine triethiodide, 21.81% of Br in pancuronium bromide 17.84% of Cl in suxamethonium chloride and 09.87% of Cl in tubocurarine chloride)

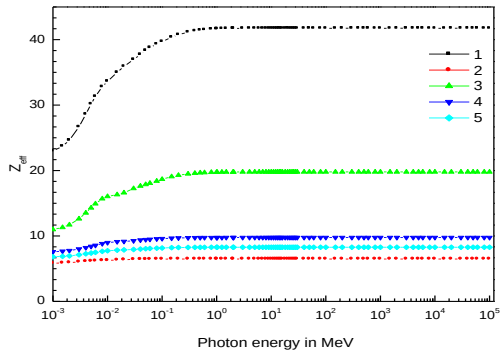

Fig:7 Variation of Z_{eff} with Photon energy E in MeV for coherent
(1)Gallamine triethiodide (2) Mephenesin
(3) Pancuronium bromide(4) Suxamethonium chloride (5) Tubocurarine chloride

The variation of N_e with photon energy of all relaxants for incoherent scattering process is similar to that of Z_{eff} and is as shown in the figure 8

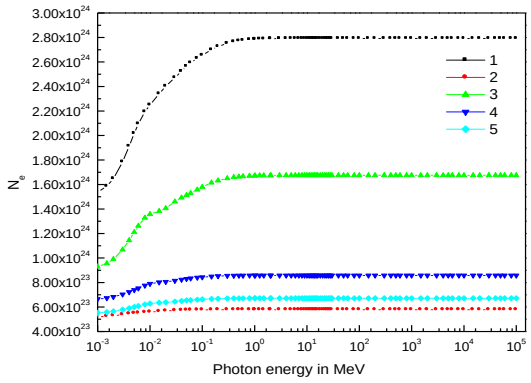

Fig: 8 Variation of N_e with Photon energy E in MeV for coherent scattering
(1) Gallamine triethiodide (2) Mephenesin
(3) Pancuronium bromide(4) Suxamethonium chloride (5) Tubocurarine chloride

Pair production in electric field:

The variation of Z_{eff} with photon energy for Pair production in electric field is as shown in the figure 9. It shows that Z_{eff} is constant with increase in photon energy from 3MeV to 30MeV i.e. independent of energy. It slightly decreases from

30MeV to 1000MeV and thereafter remains constant for all relaxants. Here also, in case of gallamine triethiodide and pancuronium bromide, Z_{eff} values are slightly more compared to the other relaxants. This is due to the large range of atomic number of constituent elements in them.

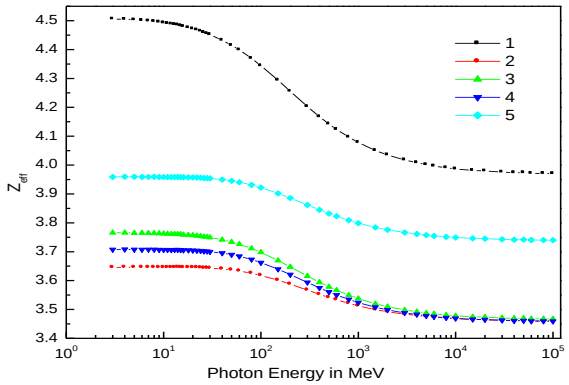

Fig: 9 Variation of Z_{eff} with Photon energy E in MeV for pair-production in electricfield
(1) Gallamine triethiodide (2) Mephenesin (3) Pancuronium bromide
(4) Suxamethonium chloride
(5) Tubocurarine chloride

The variation of N_e with photon energy of all relaxants for Pair production in electric field is similar to that of Z_{eff} and is as shown in the figure 10

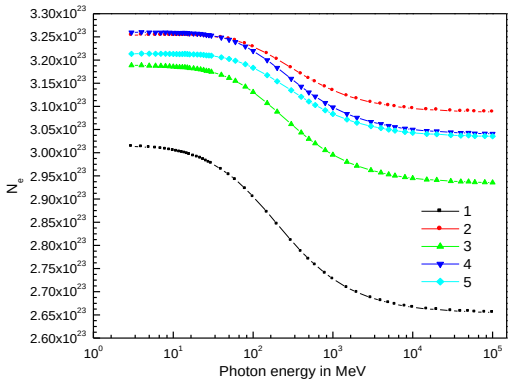

Fig: 10 Variation of N_e with Photon energy E in MeV for pair-production in electric fiel
(1) Gallamine triethiodide (2) Mephenesin
(3) Pancuronium bromide (4) Suxamethonium chloride (5) Tubocurarine chloride

Pair production in nuclear field:

The variation of Z_{eff} with photon energy for Pair production in nuclear field is as shown in the figure 11 and it shows that Z_{eff} slightly decreases with increase in photon energy from 1.25MeV onwards and found to remain constant thereafter. This is because of the fact that pair production in nuclear field is Z^2 dependent. In case gallamine triethiodide and pancuronium bromide the variation of Z_{eff} values is more compared to the other relaxants This is due to the large range of atomic number of constituent elements in them.

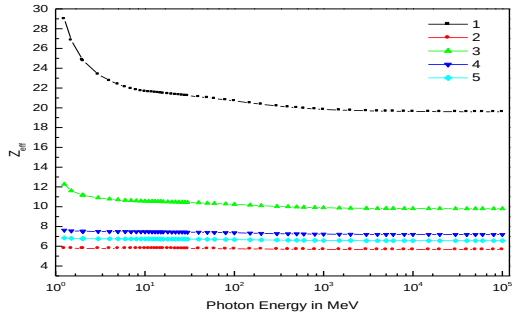

Fig: 11 Variation of Z_{eff} with Photon energy E in MeV for pair-production in nuclear field
(1)Gallamine triethiodide (2) Mephenesin
(3) Pancuronium bromide
(4) Suxamethonium chloride (5) Tubocurarine chloride

The variation of N_e with photon energy of all relaxants for Pair production in nuclear field is similar to that of Z_{eff} and is as shown in the figure 12

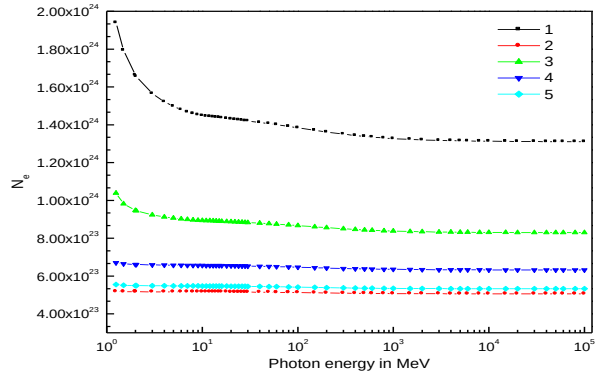

Fig: 12 Variation of N_e with Photon energy E in MeV for pair-production in nuclear field
(1)Gallamine triethiodide (2) Mephenesin
(3) Pancuronium bromie (4) Suxamethonium chloride (5) Tubocurarine chloride

Usually above relaxants may be administered to the patient before treatment. Hence while treating tissue inhomogenity of the patient, the contribution of CT numbers of relaxants has to be considered, though the values are very small. The CT numbers for total photon interaction is given in the table 2. The CT numbers for coherent, incoherent, and photoelectric absorption region and total photon interaction

helps in visualizing the image of the biological samples and precise accuracy in treating the inhomogenity of them in medical radiology.

Table 2 CT numbers of skeletal muscle relaxants

Energy in MeV	CT Numbers for Total photon interaction				
	1	2	3	4	5
1.00E-03	0.27	-0.35	-0.42	-0.32	-0.34
2.00E-03	0.68	-0.38	0.61	-0.34	-0.37
5.00E-03	7.73	-0.41	1.03	1.15	0.38
1.00E-02	12.31	-0.41	1.40	1.43	0.53
2.00E-02	12.76	-0.32	13.66	1.29	0.49
1.00E-01	4.42	-0.04	0.64	0.02	-0.02
2.00E-01	0.72	-0.03	0.07	-0.02	-0.04
5.00E-01	0.00	-0.03	-0.04	-0.03	-0.04
1.00E+00	-0.07	-0.03	-0.05	-0.03	-0.04
2.00E+00	-0.07	-0.03	-0.04	-0.03	-0.04
5.00E+00	0.07	-0.04	0.00	-0.02	-0.04
1.00E+01	0.32	-0.06	0.07	0.00	-0.04
2.00E+01	0.66	-0.08	0.17	0.02	-0.04
5.00E+01	1.06	-0.10	0.28	0.05	-0.03
1.00E+02	1.23	-0.12	0.33	0.06	-0.03
2.00E+02	1.30	-0.12	0.35	0.06	-0.03
5.00E+02	1.32	-0.12	0.35	0.06	-0.03
1.00E+03	1.32	-0.12	0.35	0.06	-0.03
2.00E+03	1.32	-0.12	0.35	0.06	-0.03
5.00E+03	1.31	-0.12	0.35	0.06	-0.03
2.00E+04	1.31	-0.12	0.35	0.06	-0.03
4.00E+04	1.31	-0.12	0.35	0.06	-0.03
8.00E+04	1.31	-0.12	0.35	0.06	-0.03
1.00E+05	1.31	-0.12	0.35	0.06	-0.03

ACKNOWLEDGEMENT

The authors are thankful to Prof.L Gerward for providing WinXCOM computer programme and encouragement to carry out the work.

REFERENCES

[1] Berger.M.J. and Hubbell.J.H XCOM: Photon cross sections on a Personal computer NBSIR 87-3597, (1987).

[2] Bhandal G. S and Singh K Effective atomic numbers studies indifferent biological samples for partial and total photon interaction in the energy region 10^{-3} to 10^{5}MeV.Int. J. Appl.Radiat. Isot. 44,429. (1993)

[3] Govinda Nayak. N,Vijaya .M.G,Siddappa.K. Effective atomic numbers of some polymers and other materials for Photoelectric process at 59.54KeV.61,559,(2001).

[4] Hine,G.J The effective atomic numbers of materials for various gamma interactions.Phys.Rev.85, 725, (1952).

[5] Hubbell. J H; Seltzer, S M, Tables of mass attenuation cofficients1KeV to 20MeV for elements Z=1 to Z=92 and 48 additional selected substances of dosimetric interest NISTIR-5632, (1995).

[6] Jakson. D. F and Hawkes.D. J X-ray attenuation coefficients of elements and mixtures, Phys. Reports, **70,169**-233, (1981).

[7] Kiran Kumar. T, Venkataratnam.S.and Venkatreddy.KComments on theoretical limitation for experimental values of photoelectric cross sections at low energies. Nucl.instrum. meth. B108, 267, (1996).

[8] Kiran Kumar. T, Venkataratnam.S.and Venkatreddy.K. Effective atomic number studies in clay minerals for total photon interaction in the energy region 10KeV to 10 MeV. Rad.Phys.Chem.48, 707, (1996).

[9] Orhan Icelli and Salih Erzeneoglu (2004) Effective atomic numbers of some vanadium and nickel compounds for total photon interactions using transmission experiments. 4Journal of Qualitative spectroscopy and Radiative Transfer, **85**, 115

[10] Parthasaradhi.K., Guruprasd.S. and Rao.B.M. (1989) Effective atomic numbers of biological materials in the energy regions 1-50 MeV for photons,electrons and He ions. Med.Phys.16,653

[11] Shivalinge Gowda, Krishnaveni.S, Ramakrishna Gowda, Studies on effective atomic number and electron density of some amino acids in the energy region 30- 1333KeV, Nucl.Inst. Meth.Phys. Res.B,239,36, (2005).

[12] Shivaramu (2002) Effective atomic numbers for photon energy absorption and photon attenuation of tissues from human organs, Medical Dosimetry, **27**, 1-9.

[13] Shivaramu,Amutha.R,Ramprasath.V. Effective atomic numbers and mass attenuation coefficients of some thermo luminescent dosimetric compounds for total photon interactions.Nucl.Sci.Eng 132,148 (1999)

[14] Shivramu,Ramprasath.V. Effective atomic numbers for photon-energy absorption and energy dependence of some thermo luminescent dosimetric compounds. Nucl.Inst. Meth.B168, 294/304.2000

[15] S J Thomas. Relative electron density calibration of CT scanners for radiotherapy treatment planning. The British Journal of Radiology, 72,781-786,1999

