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Effect of weight fraction of different constituent elements on the total mass attenuation coefficients of biological materials

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Abstract. The mass attenuation coefficients, μ_m, of biological materials have been studied as a function of weight fraction of constituent elements (hydrogen, carbon, oxygen and nitrogen). A considerable change in μ_m is seen only in low energy region whereas no change is observed with the increasing percentage of constituent elements in high energy region up to 10 MeV. The results have been presented in graphical form.

Keywords. Weight fraction; attenuation coefficient; biological material.

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That the radiations can be hazardous as well as useful to different organisms of the body is well-known to any informed person today. Their penetration and diffusion in body can be characterized by the study of a parameter namely photon attenuation coefficient. A large number of photon attenuation measurements, calculations and compilations have been made for different materials [1–8]. The attenuation coefficient has been studied as a function of different parameters. But such studies have to give more attention to biological materials. So in this direction an attempt has been made to study the effect of H, C, O and N weight fractions on the mass attenuation coefficient of biological materials which are listed in table 1.

The total mass attenuation coefficients of the chosen biological materials were computed with the help of a convenient and state-of-the-art computer program by Berger and Hubbell [9] named XCOM: 'Photon Cross Sections on a Personal Computer', in the energy range up to 10 MeV.

The variation of the computed values of μ_m due to weight fractions of different constituent elements is shown in the form of graphs (figures 1–4).

Figure 1 depicts the plot of μ_m vs. hydrogen weight fraction. From this graph, it is seen that at low energies up to 0.8 MeV, initially there is a sharp decrease in μ_m having a large negative slope and then in the middle energy region slope is positive with small value

Table 1. Weight fraction of H, C, N and O of biological materials.

Material	%H weight fraction	Material	%C weight fraction	Material	%N weight fraction	Material	%O weight fraction
Bone	6.4	Muscle	12.3	Bone	2.7	Cholesterol	3.7
Flesh	10.15	Flesh	18.27	Flesh	3.05	Chlorophyll	8.3
Muscle	10.2	Bone	27.8	Muscle	3.5	Haemoglobin	18.5
Haemoglobin	13.5	Haemoglobin	50.99	Chlorophyll	5.81	Bone	41.0
Chlorophyll	14.94	Chlorophyll	68.46	Haemoglobin	15.3	Flesh	65.99
Cholesterol	21.0	Cholesterol	75.0			Muscle	72.89

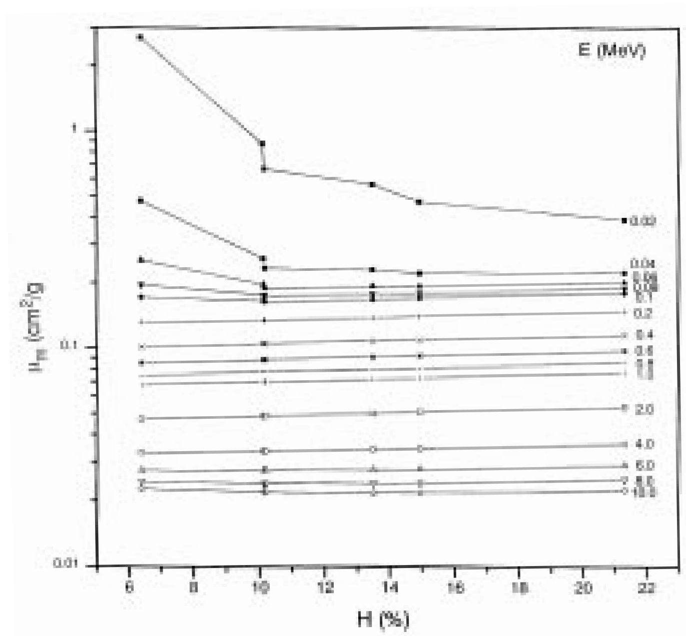

Figure 1. Plot of μ_m (cm^2/g) vs. hydrogen weight fraction at some energies.

but outside the limits of errors. In the higher energy region the change in μ_m is negligible with the increase in hydrogen percentage.

The plot of μ_m vs. carbon weight fraction is shown in figure 2. In this case, at low energies, i.e., up to 60 keV there is no linear relationship between μ_m and C weight fraction whereas no change is observed in μ_m with increasing carbon weight fraction at high energies.

Figure 3 represents a plot of μ_m vs. oxygen weight fraction. Here, in the low energy region, μ_m increases with increase in weight fraction of oxygen and then decreases above 40% weight fraction of oxygen. But this trend is limited up to energies less than 0.1 MeV. At high energies similar to the above results, more or less, there is no effect on μ_m of biological materials due to oxygen weight fraction.

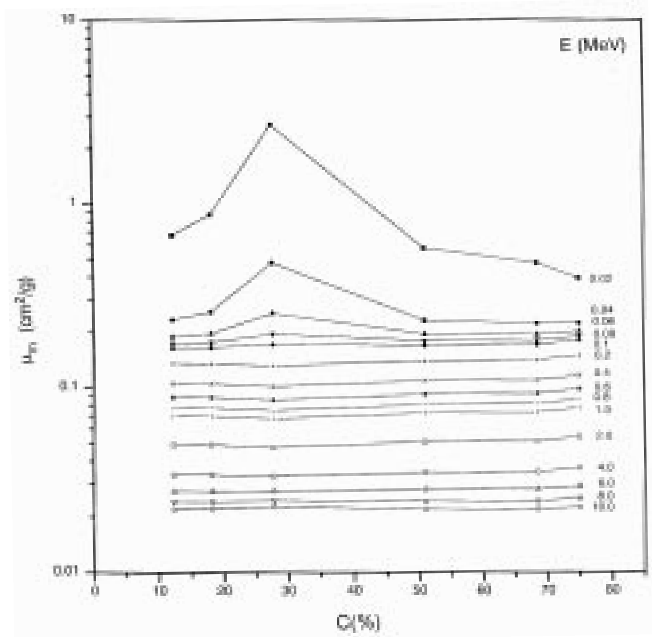

Figure 2. Plot of μ_m (cm^2/g) vs. carbon weight fraction for some energies.

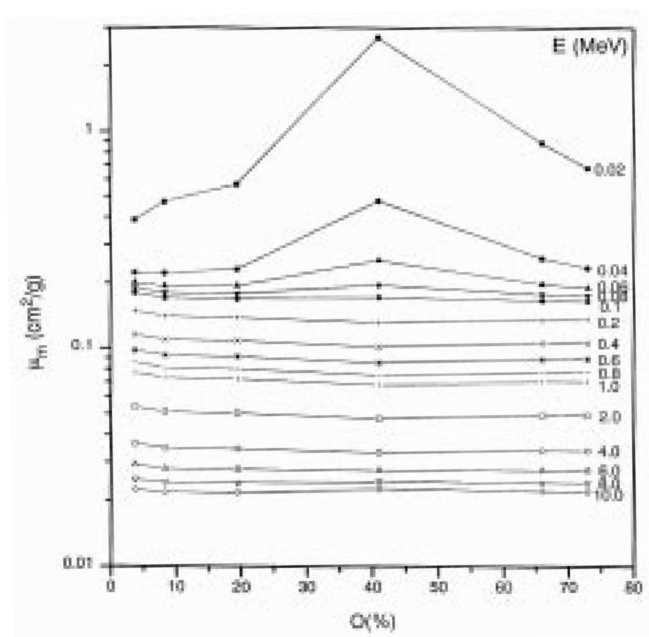

Figure 3. Plot of μ_m (cm^2/g) vs. oxygen weight fraction at some energies.

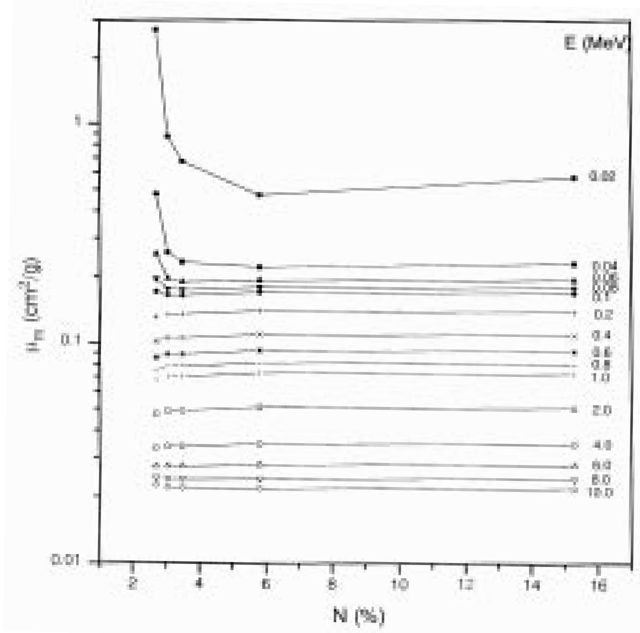

Figure 4. Plot of μ_m (cm^2/g) vs. nitrogen weight fraction at some energies.

Figure 4 is a plot of μ_m vs. nitrogen weight fraction which shows a different trend from those of H, C, and O weight fractions. At low energies up to 0.1 MeV, there is an exponential decrease in the μ_m values, which then increases linearly with increasing nitrogen weight fraction. At higher energies (above 0.2 MeV), there is no variation in μ_m with increase in nitrogen weight fraction.

In a nutshell, the results predict that considerable change in μ_m is seen only in the low energy region which is a clear justification of the previous results of our group [6], where it has been reported that variation in total μ_m at a particular energy is negligible in the medium energy region of about 150 keV to 5 MeV. This negligible variation in μ_m in the middle energy region is due to the linear Z-dependence of Compton scattering process which is the most dominant interaction process in this energy region.

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