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Determination of Radiological Data of Lipids Using Gamma Ray Spectrometry

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ABSTRACT
The absorption effects of gamma radiations on lipids are shown using radiological parameters such as mass attenuation coefficients, total attenuation cross section and molar extinction coefficient. Which will be useful, particularly in the energy region of 122 to 1330keV photon energies, by performing transmission experiments using gamma active sources ^{57}Co, ^{133}Ba , ^{22}Na ^{137}Cs ,^{54}Mn, and ^{60}Co sources. Accurate values of these physical parameters provide essential data in medical physics have been calculated for some sphingolipids were measured using gamma ray spectrometry with energy resolution 8.2% at 663 keV was used for detection. Gamma ray transmission method with a narrow beam good geometry set up is used in the study. Observed values are decrease initially and then tend to be almost constant at higher energies. Experimental results of radiological parameters were observed in good agreement with WinXCom values.

Keywords: Gamma ray Spectrometry, lipids, Mass attenuation coefficients (μ_m), Molar extinction coefficient (ε),Radioactive sources, Total attenuation cross section (σ_{tot}), WinXCom program.

1. INTRODUCTION

A living cell is a dynamic biological system composed primarily of carbohydrates, lipids, nucleic acids, and proteins that structurally and functionally interact with many other molecules to carry out normal cell metabolism. The present research work is about effect of radiation on such types of lipids and it is rather well documented that plasma membrane of mammalian tissues are rich in sphingolipids and especially sphingoglycolipids. Sphingolipids were first described by [1] in A Treatise on the Chemical Constitution of Brain. Sphingoglycolipids are a family of complex lipids with structures representing a large variety of carbohydrate compositions which are characteristics for a mammalian organ and can vary depending on the species of origin [2]. The study of siphingoglycolipid composition in various, radiosensitive and non-radiosensitive tissues, might indicate whether damages induced by the ionizing radiation on the plasma membrane matrix are involved in the process of cell death [3]. So in this research work we focus the effect of radiation on lipids at medical, radiological, biological research point of view.

Biological significance of sphingolipids; Sphingolipids are found in essentially all animals, plants, and fungi, as well as some prokaryotic organisms and viruses. They are mostly in membranes, but are also major constituents of lipoproteins. The functions of sphingolipids are still being discovered, but there are at least three, i.e., structure, recognition and signal transduction [4]. Later studies fulfilled Thudichum's faith in the value of basic research when several genetic diseases were found to have elevated amounts of sphingolipids (such as sphingomyelin in Niemann-Pick's disease and cerebrosides in Gaucher's disease) arising from defects in enzymes responsible for sphingolipid turnover, activator proteins for such enzymes, or lipid trafficking [5,6]. This knowledge allowed development of methods for diagnosis of such sphingolipid storage diseases, screening of families at risk, and, for at least Gaucher's disease, some degree of correction of the disorder by enzyme replacement. There are also indications that sphingolipids and sphingolipid analogs may be useful for prevention and treatment of disease, e.g., gangliosides [7] and alpha-galactosylceramide have potent effects as modulators of the immune system, ceramide-coated balloon catheters limit neointimal hyperplasia after stretch injury in carotid arteries [8] and dietary sphingolipids protect against colon tumorigenesis [9]. So, the relation between radiation and sphingolipids is very much important in medical and research context. Because the research area of absorption, penetration, attenuation and photon interactions with biological material such as amino acids, fatty acids, lipids, vitamins, and carbohydrates is essential in radiation medicine and biology, nuclear technology and space research[10]. The

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study of photon interactions with matter is important and the data on the transmission and absorption of X-rays and gamma rays in biological shielding and dosimetric materials assumed great significance by virtue of the diverse application in the field of medical physics and medical biology [11, 12] [13] reported μ_{en}/ρ data for elements, compound and mixtures as a function of energy of photons [14]. Selection of material for radiation shielding and protection needs an accurate assessment of interaction parameters [15].

There have been recent experimental and theoretical investigations [16,17] to determine Absorption coefficient, mass attenuation coefficients, total attenuation cross section and such type of radiological parameters for complex biological molecules such as lipids, carbohydrates, proteins, fats and oils composed of H, C, N and O elements in varying proportions.

2. THEORY

In this section, some theoretical relations are summarized that have been used for the determination of mass absorption and related parameters in the present work. When a monochromatic beam of gamma ray photons is incident on a target, some photons are emitted due to the dominant interaction processes and therefore, the transmitted beam is attenuated. The extent of attenuation depends on given elemental target. This attenuation of the beam is expressed by the following equation:

$$I = I_0 e^{-\mu t} \qquad (1)$$

where I_0 and I are the incident and transmitted photon intensities, respectively, μ (cm^{-1}) is the linear attenuation coefficient of the material and t (cm) is the sample thickness. Rearrangement of Eq. (1) yields the following equation for the linear attenuation coefficient:

$$\mu = \frac{1}{t}\ln\left(\frac{Io}{I}\right) \qquad (2)$$

In Eq. (2), the mass attenuation coefficients μ_m ($cm^2\ g^{-1}$) for the samples were obtained from Eq. (3) by using the density of the corresponding samples:

$$\mu_m = \frac{\mu}{\rho}\left(cm^2 g^{-1}\right) = \frac{1}{\rho t}\ln\left(\frac{Io}{I}\right) \qquad (3)$$

where ρ (g/cm^3) is a measured density of the corresponding sample. The values of mass attenuation coefficients were then used to determine the total attenuation cross section(σ_{tot}) by the following relation

$$(\sigma_{tot}) = \mu_m (M / N_A) \qquad (4)$$

where M= $\sum_i n_i A_i$ is the molecular weight of the compound, N_A is the Avogadro's number.

And the values of molar extinction coefficients were determined using the following relation:

$$\varepsilon = 0.4343 N_A \sigma_{tot} \qquad (5)$$

All these radiological parameters are convenient parameters used to characterize the radiation response of a multi-element material in many technical and medical applications. Accurate values of these physical parameters provide essential data in medical physics.

3. EXPERIMENTAL SET UP AND MEASUREMENTS

The gamma active radioactive sources ^{57}Co, ^{133}Ba , ^{22}Na ^{137}Cs ,^{54}Mn, and ^{60}Co were used in the present investigation having energies 122, 356, 511, 662, 835, 1173, 1275 and 1332 keV emitted by the above radioactive sources were collimated and detected by the NaI (Tl) based gamma ray spectrometry. The signals from the detector were amplified and analyzed with 13-bit multichannel analyzer. In the present study, samples of lipids (sphingolipids) are in powder form which are 99.9% pure and by using KBr press machine it converted into pellet forms (0.13 g/cm^2 of uniform thicknesses) shaped and confined in a cylindrical plastic

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container having the same diameter as that of sample pellets. The diameters of the samples were determined with the help of a traveling microscope. These pellets are placed on an empty plastic container which play a role of substrate. It was observed that the attenuation of photons of the empty containers were negligible. The sample thickness was selected in order to satisfy the following ideal condition as far as possible [4]: $2 < \ln (I_0 /I) < 4$.

The schematic view of the experimental set up is displayed in Fig.1. From the measured values of unattenuated photon intensity I_0 (with empty plastic container) and attenuated photon intensity I (with sample), the mass attenuation coefficients (μ_m) for all the samples of sphingolipids were calculated using Eq.(3). The experimental values of mass attenuation coefficients were compare against the Win-Xcom program by [2] at all photon energies of current interest which, can give the theoretical numerical data of all compounds, mixture, metal, alloys for references. The contribution of coherent as well as incoherent scattering at such angles in the measured cross-sections at intermediate energies is negligible. Hence, no small angle scattering corrections were applied to the measured data. The error due to the sample impurities can be high only when large percentage of high Z impurities is present in the sample. The samples sphingolipids are used in the present study were of high pure and sample impurity corrections were not applied to the measured data. Here all the radiological quantities; mass attenuation coefficients, total attenuation cross section and molar extinction coefficient are determined by using equations 1 to 5.

4. FIGURES AND TABLES

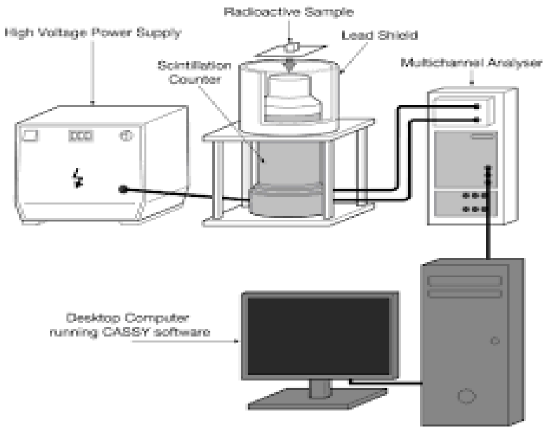

Fig-1: The schematic view of Scintillation counter.

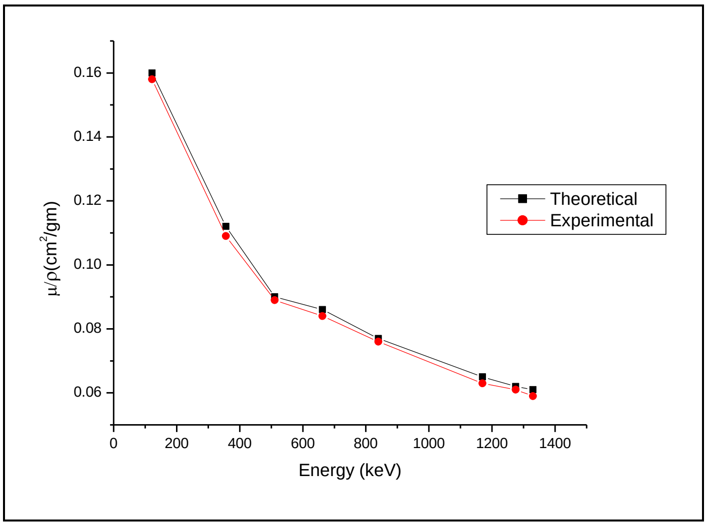

Fig-2: Plot of μ_m versus photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

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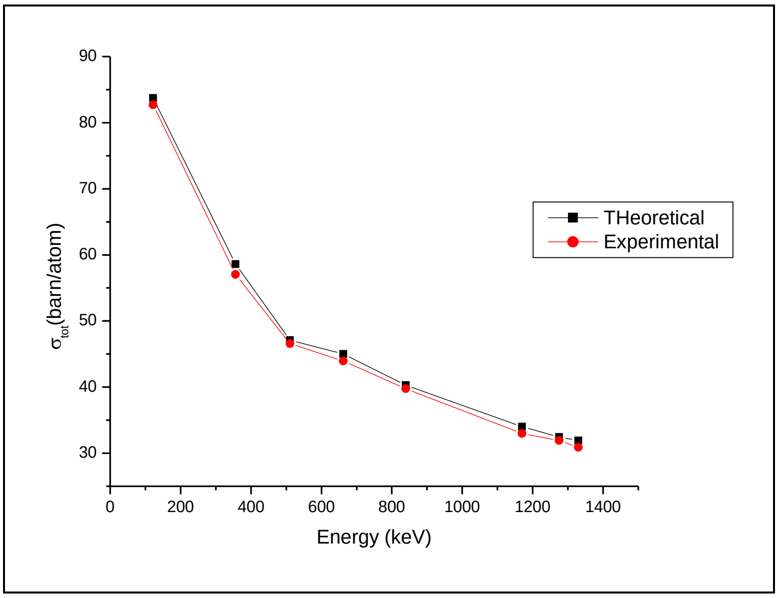

Fig-3: Plots of σ_{tot} versus photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

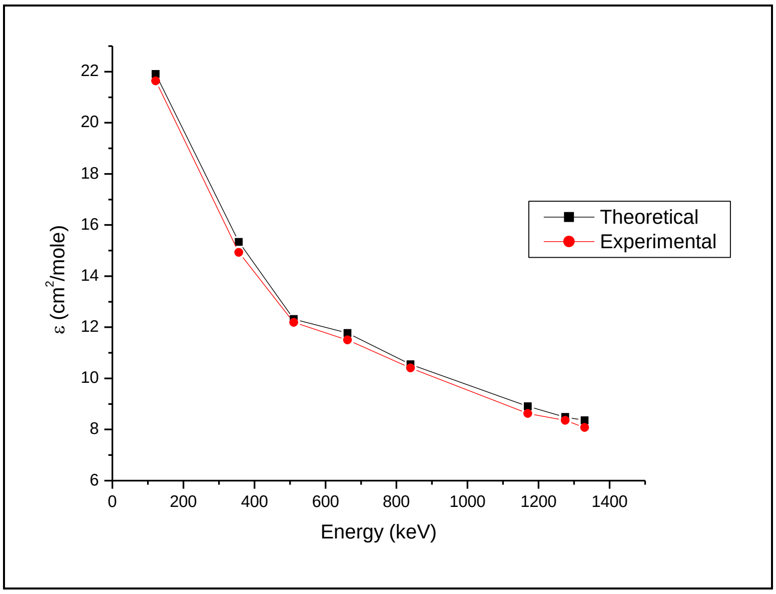

Fig-4: Plots of $_{\varepsilon}$ versus photon energy for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$).

Table-1: Mean atomic numbers (Z) calculated from the chemical formula for sphingolipids.

Sphingolipids	Molar mass (g/mol)	Chemical Formula	Mean atomic number, Z
Dehydrophytosphingosine	315.28	($C_{18}H_{37}NO_3$)	3.11
Myriocin	401.28	($C_{21}H_{39}NO_6$)	3.31
Hemsleyin imine A	605.57	($C_{39}H_{75}NO_3$)	2.89

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Table-2: Comparison of measured and calculated values of mass attenuation coefficient (μ_m cm^2/g) of sphingolipids at different photon energies. The calculated values are based on Win-XCOM program.

Sr. No.	Sphingolipids	122keV Exp.	122keV Theo.	356keV Exp.	356keV Theo.	511keV Exp.	511keV Theo.	662keV Exp.	662keV Theo.	835keV Exp.	835keV Theo.	1173keV Exp.	1173keV Theo.	1275keV Exp.	1275keV Theo	1332 keV Exp.	1332 keV Theo.
1.	Dehydrophytosphingosine	0.158	0.160	0.109	0.112	0.089	0.090	0.084	0.086	0.076	0.077	0.063	0.065	0.061	0.062	0.059	0.061
2.	Myriocin	0.156	0.158	0.107	0.110	0.092	0.094	0.086	0.085	0.075	0.076	0.066	0.064	0.060	0.061	0.058	0.060
3.	Hemsleyin imine A	0.163	0.161	0.110	0.112	0.098	0.096	0.085	0.087	0.076	0.077	0.067	0.066	0.064	0.063	0.060	0.062

Table-3: Comparison of measured and calculated values of total attenuation cross section (σ_{tot} barn/atom) of sphingolipids at different photon energies. The calculated values are based on Win-XCOM program.

Sr. No.	Sphingolipids	122keV Exp.	122keV Theo.	356keV Exp.	356keV Theo.	511keV Exp.	511keV Theo.	662keV Exp.	662keV Theo.	835keV Exp.	835keV Theo.	1173keV Exp.	1173keV Theo.	1275keV Exp.	1275keV Theo	1332 keV Exp.	1332 keV Theo.
1.	Dehydrophytosphingosine	82.6811	83.7277	57.0395	58.6094	46.5735	47.0968	43.9570	45.0036	39.7706	40.2939	32.9678	34.1440	31.9212	32.4445	30.8746	31.9212
2.	Myriocin	103.9022	105.2343	71.2663	73.2644	61.2757	62.6077	57.2794	56.6134	49.9530	50.6190	43.9586	42.6265	39.9624	40.6284	38.6303	39.9624
3.	Hemsleyin imine A	163.8343	161.8241	110.5630	112.5733	98.5016	96.4914	85.4350	87.4453	76.3890	77.3941	67.3429	66.3378	64.3276	63.3224	60.3071	62.3173

Table-4: Comparison of measured and calculated values of molar extinction coefficient (ε cm^2/mol) of sphingolipids at different photon energies. The calculated values are based on Win-XCOM program.

Sr. No.	Sphingolipids	122keV Exp.	122keV Theo.	356keV Exp.	356keV Theo.	511keV Exp.	511keV Theo.	662keV Exp.	662keV Theo.	835keV Exp.	835keV Theo.	1173keV Exp.	1173keV Theo.	1275keV Exp.	1275keV Theo	1332 keV Exp.	1332 keV Theo.
1.	Dehydrophytosphingosine	21.6343	21.9081	14.9249	15.3357	12.1864	12.3233	11.5017	11.7756	10.4063	10.5433	8.6263	8.9001	8.3524	8.4894	8.0786	8.3524
2.	Myriocin	27.1870	27.5355	18.6475	19.1703	16.0333	16.3819	14.9877	14.8134	13.0706	13.2449	11.5022	11.1536	10.4565	10.6308	10.1080	10.4565
3.	Hemsleyin imine A	41.5538	42.0798	28.6668	29.4558	23.4069	23.6699	22.0919	22.6179	19.9879	20.2509	16.5689	17.0949	16.0429	16.3059	15.5169	16.0429

5. RESULTS AND DISCUSSION

The values of mean atomic numbers calculated from the chemical formulae of sphingolipids studied in the present work are displayed in Table1. The experimentally measured values of μ_m (cm^2/g) for some sphingolipids such as Dehydrophytosphingosine, Myriocin, Hemsleyin imine A at 122, 356, 511, 662,835, 1173, 1275 and 1332 keV photon energies tabulated in Table 2. The typical plot of μ_m versus energy E for Dehydrophytosphingosine ($C_{18}H_{37}NO_3$) is displayed in Fig.(2). The Fig.(2) also includes the variation of theoretically determined μ_m values versus energy. It is clearly seen that the μ_m depends on photon energy and decreases with increasing photon energy. The experimental (μ_m) values agree with theoretical values calculated using the Win-XCom program. The total experimental uncertainty of the (μ_m) values depend on the uncertainties of I_0 (without attenuation), I (after attenuation), mass thickness measurements and counting statistics. Typical total uncertainty in the measured experimental (μ_m) values is estimated to be 2-3%. Measured total atomic cross section (σ_{tot}) and molar extinction coefficient (ε) values for the presently studied sphingolipids have been displayed in Table 3 and Table 4, respectively. The typical plots of σ_{tot} versus E and ε versus E are displayed in Figs.(3) and Fig.(4) respectively. The behavior of σ_{tot} and ε with photon energies shows almost similar behavior to (μ_m) plots. All calculations of molar extinction are done according to

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XCOM program and our calculations are based on Win-XCom which is updated version of XCOM also arrange narrow beam good geometry setup for performing experiment.

The present experimental study has been undertaken to get information on mass attenuation coefficient μ_m values and related parameters σ_{tot}, ε for bio-molecules samples which are convenient parameters used to characterize the radiation response of a multi-element material in many technical and medical applications. Accurate values of these physical parameters provide essential data in medical physics and mainly in dosimetry. The μ_m and related quantities were found to decrease with increasing photon energies. The measured data were compared against Win-XCom program.

6. CONCLUSIONS

- The biological effect of ionizing radiation on human being depends on absorber dose, types of radiation alpha, beta, gamma and organs irradiated Photon entering the bodies not only lose but also they give rise energy and are finally absorbed, but also they give rise to new photons by multiple scattering gamma and X-rays are use for diagnostic in nuclear medicine, computed tomography scanning, radiography, radiotherapy, gamma knife radio surgery etc for treatment of many diseases.
- The results on μ_m, ε, Z_{eff}, and N_{eff} of biological C,H,N,O based compounds, reported in the present work, would be useful, particularly in the energy region of interest, in many medical and biological applications (e.g. for the interpretation of absorbed dose), and in radiation shielding and protection.
- With proper knowledge of the attenuation parameters and buildup of photons in human organs and tissues, energy-absorption in the human body can be carefully controlled. The experimental data will also help in estimating safe dose levels for radiotherapy patients. For people working with gamma radiation and X-rays, especially at reactors and nuclear power plants, the present studies on the energy-absorption factor of human organs and tissues will help them to take proper precautions.

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