PART - I
CHAPTER 1

Review of Literature
Knowledge of the mass attenuation coefficients is of prime importance in the measurements. Hence it is important to the tabulations of mass attenuation coefficients in different composite materials. The mass attenuation coefficient is a measure of average number of interactions between incident photons and matter that occur in a given mass per unit area of thickness of material. On the other hand, mass energy absorption coefficient is a measure of the average fractional amount of incident photon energy transferred to kinetic energy of charged particles as a result of interaction. This imparted charged particle kinetic energy, in turn, is more or less valid approximation, depending on the absorber, absorber dimensions, photon energy and other factors, to the amount of the energy made available for the production of chemical, biological and other effects associated with exposure to ionizing radiation, Berger (1961). Hubbell (1982) has recently reviewed mass attenuation coefficients and mass absorption coefficients for 40 elements ranging from hydrogen \((Z = 1)\) to uranium \((Z = 92)\) for photon energies 1 keV to 20 MeV and for H, C, N, O, Ar and seven mixtures from 0.1 keV to 20 MeV (including the \(^{137}\)Cs and \(^{60}\)Co gamma ray energy explicitly) in addition to the contributions from scattering, photoeffect and pair production (1977). A useful tabulation of photon mass attenuation coefficients and mass energy absorption coefficients for 45 dosimetry related materials has also been
given by Hubbell (1982). The changes in mass attenuation coefficients and effective atomic numbers for partial and total photon interactions as a function of their chemical composition has been investigated by Bhandal et. al (1992).

Accurate values of mass attenuation coefficients are necessary to establish the region of validity of theory based parametrization, in addition to providing essential data in such diverse field such as tomography, x ray fluorescence studies, geophysical prospecting, shielding studies and radiation biophysics. Measurements of hydrocarbons in the energy range 33 - 662 keV were performed by Bradley et.al (1986), where a regularity in the relationship between the mass attenuation coefficients and hydrogen weight fraction was revealed. They found considerable sensitivity of total mass attenuation coefficients to variations in hydrogen content of variety of heterogeneous compounds and substances. In respect of energy absorption from incident gamma rays, Bradley et. al (1989) proposed the use of sphere transmission method for direct measurement of energy absorption coefficients for materials in solid form. Measurements on substances containing H, C, O in the energy range 45 - 1333 keV were also performed by El - Kateb and Hamid (1991), and derived the straight line relationship between hydrogen weight fraction and total mass attenuation. In addition to this, effective atomic numbers were found to be constant as a
function of energy. In the same energy range Perumallu et al (1984) measured mass attenuation coefficients and calculated the total cross sections and effective atomic number of some chlorides, nitrates and sulphates.

Adams (1948) measured the absorption of quanta between 11 to 20 MeV of x rays from 22 MeV betatron as a source by using used aluminum, iron, copper and lead as absorbers. Alburger (1948) studied the absorption of sodium (24) gamma radiation in lead, copper and aluminum with a Geiger - Muller counter and calculated theoretical values from Heitler's curves for the gamma rays of energies 2.76 MeV and 1.38 MeV.

Appoloni et al (1994) measured the mass attenuation coefficients of the L-Rd-A, Brazilian soil has been measured at seven energies in the range of 59.5 to 1408.0 keV. Ban et al (1994) have measured photon energy absorption coefficient for air, nitrogen and argon at 30 keV by using parallel plate free air ionization chamber and results are compared the results with Hubbell's tables (1982). Berger (1961) has tabulated the x ray or energy absorption or transfer coefficient. Berger and Hubbell (1993) have calculated mass attenuation coefficients for photons for all elements at energies 1 keV to 1 GeV (hard gamma rays).

The sphere transmission method was employed for the direct measurement of the mass energy absorption coefficients.
at 662 and 1115 keV of some fatty acids by Bhandal et al. (1994) and photon attenuation coefficient and effective atomic numbers of four different cements have been calculated for total and partial photon interaction processes in the energy range 0.001 - 10,000 MeV (1993). Also these authors (1994) studied the mass attenuation coefficients and effective atomic numbers in some multielements like concrete, Bakelite (Baké), pyrex glass (pyrex), flesh, bone compact, calcareous (c) and 4 - Methyl - 5 - carboxy heptyl 1,2,3 selenadiazole (C₁₁H₁₈N₂O₂Se) etc. and found that in the case of mass attenuation coefficients, except the total interaction process, the behaviour of all composite materials is identical at all energies.

With the increasing use of radiations in many fields, such as industry, medicine and agriculture, several scientists have tried to study in depth various gamma ray interactions in composite materials such as bones, plastics, alloys and water. Coppola and Reiniger (1974) have studied the influence of chemical composition on mass attenuation coefficients from 10 keV to 3 MeV for total photon interaction process and conducted significant variation in it. Zavel'skii (1964) has proposed a direct relationship of mass attenuation coefficients with heavy materials in rocksalt for low photon energies. Perumallu et.al (1985) have suggested the Z impedance of atomic photoelectric and
coherent scattering in multielemental materials of biological importance.

Rama Rao et. al (1961) have studied the effective atomic number of alloys for pair production. Sastry and Swami Jnananda have measured attenuation coefficients in seven different alloys and in perspex for 1.1715 and 1.3316 MeV gamma radiations from 17 mc Co$^{60}$ source.

Joga Rao et. al (1985) have measured total photon attenuation coefficients in certain alloys and compounds in the energy region 6.4 - 12.1 keV employing the Si(L1) detector system. They suggested it for compilations of attenuation coefficients of elements, especially in the region of absorption edges. Mudahar and Sahota (1991) have studied total and partial mass attenuation coefficients of soil as a function of chemical composition.

The photon attenuation coefficient is an important parameter for characterizing the penetration and diffusion of X-rays and gamma ray in multielemental materials. Photon attenuation coefficients are required in variety of nuclear science, technology and medical applications. With the discovery of X and gamma rays, it became apparent that they could be harmful, and shielding to protect against them came into existence. In the shielding calculations of structures of power plants and other nuclear facilities, parameters like attenuation coefficients of engineering materials become very
useful for the practical calculations of gamma ray shielding design. Numerous attempts have recently been made to use the ratio of elastic to inelastic photon scattering for various applied purpose such as biological applications and non destructive testing and imaging. From the measurement of the coherent to compton scattering intensity ratio (R/C), Bhandal and Singh (1994) have directly determined the effective atomic number.

High energy electrons set into motion by photon interactions with matter lose some of their energy by bremsstrahlung. This loss was calculated by Cunningham and Johns (1980). With a 600 keV x ray source and two crystal spectromter, especially designed for short wavelength x rays, the mass attenuation coefficients for C, N, Al, Si, K, N, Cu, and Cu were determined for wavelengths from 50 to 209 XU by Cuykendall (1936). Cork and Pidd (1944) have calculated accurately the linear absorption coefficient for certain gamma rays in copper and lead at energies 1.14 MeV form zinc 65, 1.30 MeV from cobalt 60, and 1.38 -2.85 MeV from sodium 24. Davissson and Evans (1952) have developed theories for the different types of interaction with matter and measured the absorption of gamma rays in Al, Cu, Sn, T and Pb from I, Cu, Mn, Co, Zn, and Na.

Corner (1970) have measured total gamma ray attenuation coefficients at nine energies in the range of 88
keV to 2.75 MeV for Be, C, Mg, Al, S, Ti, Fe, Ni, Cu, Zn, Zr, Nb, Mo, Ag, Sn, La, Gd, Hf, W, Au, Pb, Th, U and Pu by using radioactive isotopes as a source of monoenergetic gamma radiation in a narrow beam collimated geometry.

Goswami and Chaudhari (1972) have measured gamma ray attenuation coefficients very accurately for 34 elements from hydrogen to lead at six photon energies by using an extremely narrow collimated beam transmission method. The transmission of gamma rays through large thickness of materials numerically calculated by Peebles and Plesset (1951). Cowan (1948) measured the absorption coefficients for gamma radiation ranging from 0.32 to 2.8 MeV penetrating various elements from low to high Z.

Walker (1949) have measured the gamma ray absorption cross sections of C, Al, Cu, Sn, and Pb for the 17.6 MeV gamma rays in the Li\(^7\(\text{p,}\gamma\)Be\(^8\) reaction by using gamma ray pair spectrometer as a detector to avoid counting lower energy quanta produced either in the Li\(^7\text{(p,}\gamma\)Be\(^8\) reaction, or as secondary radiation in the absorber.

In radiotherapy, patients are never treated under idealized narrow beam conditions. The use of absorbers within a broad radiation beam to deliver a limited dose to some tissues while giving a higher dose to other tissues is common. Often theoretical narrow beam attenuation coefficients or predetermined narrow beam half value layers
(HVL's) are used to estimate the transmission through absorbers. Furthermore, with an increasing application of very large radiation fields for total body, half body or total nodal irradiation, combined with need for dose reduction to specific organs or even dose rate reduction by the use of absorbers across the total beam. The effect of broad beam geometries on the dose to the patient when lead absorbers are used in cobalt 60 and high energy x-ray beam are reported by Dyk (1986).

Absorption of 2.8 MeV gamma rays in lead is reported by Grotzinger and Smith (1945) and the absorption coefficients of 5.8 MeV gamma radiation in aluminum by Halpern and Crane (1939).

Sphere transmission method for the measurement of atomic photoelectric cross section has been developed by Ghose (1965). This method is based on the measurement of photon transmission through spherical shells of absorbers.

Theoretical studies by Rakavy (1957) and experimental studies by Sheline (1956) have suggested the systematic occurrence of large nuclear equilibrium deformation in the region of mass number between O$_{16}$ and Si$_{28}$. The odd even nucleus was excited by photon bombardment of Na using Coumbia Van de Graaff generator. The even even nucleus Ne$_{20}$ was excited by the exoergic $(p,\alpha)$ reaction from proton bombardment of Na ($Q = +2.38$ MeV), and proton bombardment of
a natural Ne target. The de-excitation gamma rays have been studied by Kruse et al. (1960), using scintillation spectrometry, to provide further information on the applicability of the collective model to light nuclei.

Fano (1953) analysed gamma ray penetration to determined attenuation coefficients and discussed basic interaction. Mass absorption coefficients have been measured for Pb(82), Ta(73), Sn (50), Ag(47), Mo(42), and Cb(41) in the wavelength range 30 < λ < 185 Xu for high atomic number by Johnes (1936). Na$^{23}$ and Ne$^{2}$ gamma rays were observed by Kruse et al. (1969) from the photon bombardment at various energies of thin evaporated Na and NaI targets and of natural Ne gas target. Mc Daniel et al. (1947) constructed gamma ray spectrometer to measure the energy distribution and absorption of gamma rays emitted in the Li$^7$ (p,$\gamma$) Be$^8$ reaction and further calculated absorption coefficient at 17 MeV in lead and aluminum. McMillan discussed artificial nuclear disintegration and studied absorption coefficients.

Nathu Ram et al. (1981) studied the transmission of positron from $^{65}$Zn and $^{22}$Na in Be, Al, Cu, Ag, Pb and compared it with that of electrons of identical energies. These measurements were performed at atmospheric pressure. Using the simplest exponential formula and build up factor as unity, the intensity of gamma radiation was calculated as the rays traverse the source and the shell of the absorber.
The expression for the intensity at any point in the shell due to volume element of the source is investigated by Obi (1988) over the entire volume of the source to give the total gamma flux at the point. The scattering cross section for gamma rays in aluminum was measured by Parkinson (1949) by two independent methods at three energies 1.11, 1.17 and 2.76 MeV. The decay of Sn$^{103}$ has been widely studied by Phillips et. al (1960) by using fast - slow coincidence spectrometer. Roberts (1944) used condenser type of ionization chamber, which overcame many difficulties usually inherent in this kind of measurement and calculated the absorption of filtered gamma rays from radium (B + C) in aluminum, carbon and lead. The total gamma absorption cross section has been measured by Tessler and Stehens (1964) for Be$^7$ from 20.04 to 21.24 MeV, O$^{16}$ from 20.37 to 22.04 MeV, F$^{19}$ from 19.97 to 20.46 MeV and Al$^{27}$ from 20.37 to 20.88 MeV using monochromatic gamma rays from the $^1 \text{T}\,^3\,(p,\gamma)^4\text{He}$ reaction. The absorption of hard monochromatic gamma radiation has been reported by Tarrant (1931) and the total absorption cross section for a photon by an electron gas has calculated by Tzoar and Klein (1961). Seltzer (1993) has described new calculations of mass energy transfer and mass energy absorption coefficient for photon energies from 1 keV to 100 MeV. These coefficients are conversion factors which are used to relate the photon energy fluence in an irradiated medium to quantities
approximately the absorbed dose. White et. al (1977) have measured attenuation coefficients for human tissue using low energy photon radiation in the range 9.88 - 59.32 KeV for 44 elements and tissues.