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Study of photon attenuation coefficient of soil samples from Maharashtra and Karnataka states (India) at gamma ray energies from 122 keV to 1330 keV

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Abstract

A scientific study of interaction of radiation with matter demands a proper characterization and assessment of penetration and diffusion of gamma rays in the external medium. The study of attenuation coefficient of various materials has been an important part of research in Radiation Chemistry, Physics, agriculture and human health. The parameter attenuation coefficient usually depends upon the energy of radiations and nature of the material. The variation of linear and mass attenuation coefficient with different soil samples having chemical and Physical properties containing microelements has been investigated, using gamma radiation method. For this work, Soil Samples were collected from different regions of Maharashtra and Karnataka states of India and the parameters attenuation coefficients of soils were determined by performing experiment of gamma radiation on soil samples. The result represented in graphical forms. The Experimental measured values are in good agreement which validates the gamma absorption law.

Key words: Attenuation coefficient, gamma ray energy sources, gamma ray spectrometer, NaI (Tl) detector, etc.

Introduction

The Photon attenuation coefficient is an important parameter characterizing the penetration and diffusion of gamma rays in composite materials such as soil. The effects of different parameters on the attenuation coefficients of soils were discussed in several studies. Soil has chemical properties as on its compositions like C, N, S, P, Ca, Mg, Na, etc. and has Physical Properties :(i) Sand, Loam, Clay loam (ii) Moistness (iii) Water holding capacity (v) Particle density (vi) Appearance density (vii) Porosity etc. in variable concentrations. Soil contains microelements such as Cu, Fe, Mg, and Zn measured here in Part per Million.

Data on mass attenuation coefficients of gamma rays in compound and mixtures of dosimetric interest have been studied by Hubbell in the energy range of 1 kev to 20 kev[1]. An updated version of attenuation coefficients for elements having atomic number from 1-92 and for 48 additional substances have been compiled by Hubbell and Sheltzer[2]. Other scientists such as, Bradley[3], Cunningham[4], Carlsson[5], Jahagirdar[6], Singh[7], Appoloni C.R.[14], etc. studied on energy absorption coefficients. Teli and Chaudhari[15-19] studied linear attenuation and mass attenuation coefficients by dilute solutions of NaCl for varying concentrations at various gamma energies. The reports on attenuation coefficients by researchers are available in the journals[8-13,20-23], Raje and Chaudhari, studied 'Mass attenuation coefficients of soil samples in Maharashtra State (India) by using gamma energy at 0.662 MeV[22]. Chaudhari and Nathuram studied 'Absorption coefficient of polymers (poly vinyl alcohol) by using gamma energy at 0.39 MeV'[23].

In view of the importance of the study of gamma attenuation properties of materials and its various applications in science, technology, agriculture and human health, we embarked on a study of the attenuation properties of soil sample of various chemical and physical properties containing microelements by using gamma radiation technique.

Material and Methods

The mixture rule for the mass attenuation coefficient of a soil is given by, $(\mu/\rho)_i = \sum W_i [\mu/\rho]_i$ (1)

where, $(\mu/\rho)_i$ and W_i are the total mass attenuation & weighing factors respectively of the constituent elements of the compound mixture. Attenuation coefficient is a basic quantity used in calculation of penetration of materials by quantum particles or energy beams. The linear attenuation coefficient, also called the narrow beam attenuation coefficient, is a quantity, which describes the extent to which the intensity of a beam is reduced as it passes through the material. We determined the linear and mass absorption coefficients of Soil samples using gamma ray of various energies. The absorption of radiation is characterized by the equation,

$$I = I_o \exp(-\mu x) \quad (2)$$

Where I_0 is the number of particles of radiation counted during a certain time duration without any absorber, I is the number counted during the same time with a thickness *x* of absorber between the source of radiation and the detector, and μ is the linear absorption coefficient. This equation may be cast into the linear form,

$$\ln I = -\mu x + \ln I_o \quad (3)$$

The mass absorption coefficient μ_m is defined as,

$$\mu_m = \mu/\rho \quad (4)$$

Where, μ is measured in cm^{-1}, μ_m is measured in cm^2/gm and ρ is particle density of soil sample in gm/cc.

Experimental arrangement: The experimental arrangement is as shown in figure (i). Gamma ray sources of energy from 123 keV to 1330 keV. A Na (Tl) detector is in conjunction with counter circuits. The whole system was enclosed in lead castle. The detector absorbs a narrow beam of gamma rays after passing through the test column. A multichannel analyzer was used to count the signal magnitude of the transmitted gamma ray.

Observations: For this work, Soil Samples were collected from different regions of Nanded and Latur districts from Maharashtra state and Bidar district from Karnataka state of India.

A cylindrical plastic container of internal diameter 3.8 cm and height 6 cm was placed in between detector and source as shown in figure 1. The distance between detector, soil sample container and source is 3 cm each. By keeping empty container in between source and detector firstly, the number of counts I_o of gamma particles for 1000 sec was measured to remove error due to the random nature of radioactivity. Then by inserting the soil sample in container 1 cm, 2cm, etc, the number of counts I of gamma particles for 1000 sec was measured for each path length. This procedure repeated for different sources of various energies: 122, 360, 511, 662, 840, 1170, 1280 and 1330 keV. For this experiment MCB1 (U 1-2) software was used.

Firstly, the graphs of Thickness V/s (Io/I) for each soil sample and various energies are plotted. Straight lines obtained for each soil sample and for all energies, but slopes and intercepts for each are different. Slope (m) and intercept on Y-axis (c) are noted for each straight line for the calculation of linear and mass attenuation coefficients. Finally, the Energy V/s mass attenuation coefficient for each soil sample is plotted for results.

The chemical and physical property of each soil sample is given in table I (a) and (b), and Percentage of microelements in PPM is given in table II.

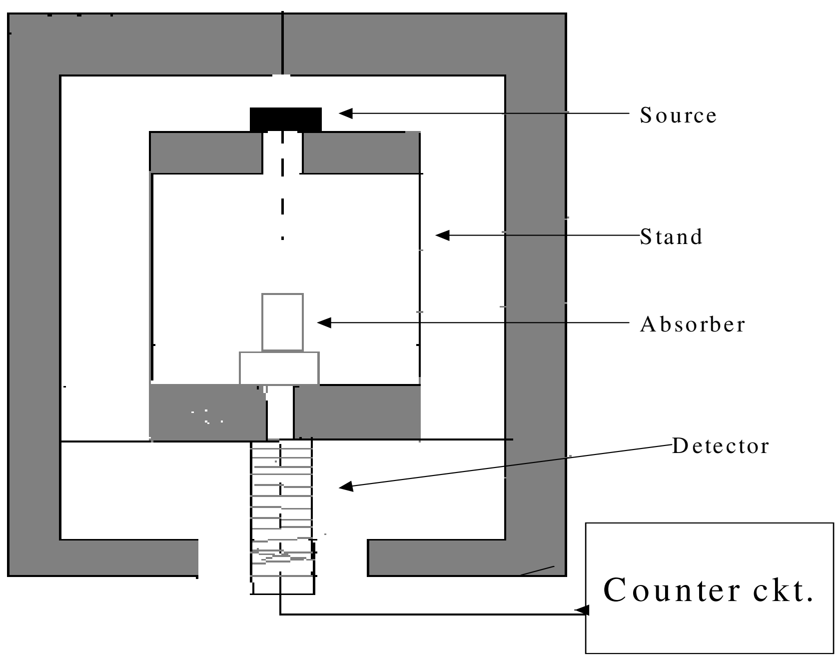

Figure-1
Experimental arrangement

Table -1
Chemical Components; kg/hector (percentage)

Sr. No.	Soil Sample	C	S	P	Ca	Mg	Na	$CaCo_3$
1	NANDED 1	1.39	28.38	310.46	37.50	49.16	12.71	5.25
2	NANDED 2	1.04	23.93	1518	37.76	56.15	4.23	7.88
3	NANDED 3	1.67	22.82	197.57	51.62	43.84	4.29	11.63
4	BIDAR 1	1.22	33.39	698.88	51.74	44.78	2.03	2.50
5	BIDAR 2	1.28	311.67	653.18	82.82	13.93	1.96	2.50
6	BIDAR 3	0.99	32.28	447.55	76.84	19.87	1.88	1.63
7	LATUR 1	1.25	31.17	729.39	63.82	33.61	1.51	5.88
8	LATUR 2	1.41	30.05	936.77	63.49	33.69	1.55	4.63
9	LATUR 3	0.77	28.94	912.58	49.64	46.65	2.07	6.63

Table -2
Physical Components; kg/hector (Percentage)

Sr. No.	Soil Sample	Sand	Moistness	Water Holding Capacity	Particle Density (gm /cc)	Porosity	Increase in Size
1	NANDED 1	48.31	4.12	51.05	2.43	58.90	33.43
2	NANDED 2	25.96	6.42	72.70	2.28	63.72	49.95
3	NANDED 3	27.31	6.35	51.52	1.97	57.54	36.69
4	BIDAR 1	32.50	11.07	50.87	2.51	61.49	36.61
5	BIDAR 2	14.16	10.07	30.42	1.86	63.14	41.19
6	BIDAR 3	24.13	5.24	50.54	2.64	62.87	33.14
7	LATUR 1	41.29	11.10	58.40	2.86	66.61	44.89
8	LATUR 2	52.49	14.53	42.56	3.65	58.14	33.92
9	LATUR 3	32.54	15.01	81.67	1.52	67.00	48.71

Table -3
Percentage of microelements (in Part Per Million)

Sr. No	Soil Sample	Microelements			
		Cu	Fe	Mg	Zn
1	NANDED 1	3.72	4.90	2.12	0.62
2	NANDED 2	2.26	4.32	2.58	0.61
3	NANDED 3	3.02	4.16	2.68	0.52
4	BIDAR 1	3.08	5.45	2.26	0.49
5	BIDAR 2	3.29	5.44	2.98	0.44
6	BIDAR 3	3.94	5.60	3.12	0.62
7	LATUR 1	4.31	5.64	2.13	0.81
8	LATUR 2	2.65	5.11	2.90	0.64
9	LATUR 3	3.40	4.90	2.21	0.54

Results and Discussion

Graphs of Energy in keV v/s Mass attenuation coefficient in cm^2/gm of soil samples plotted.

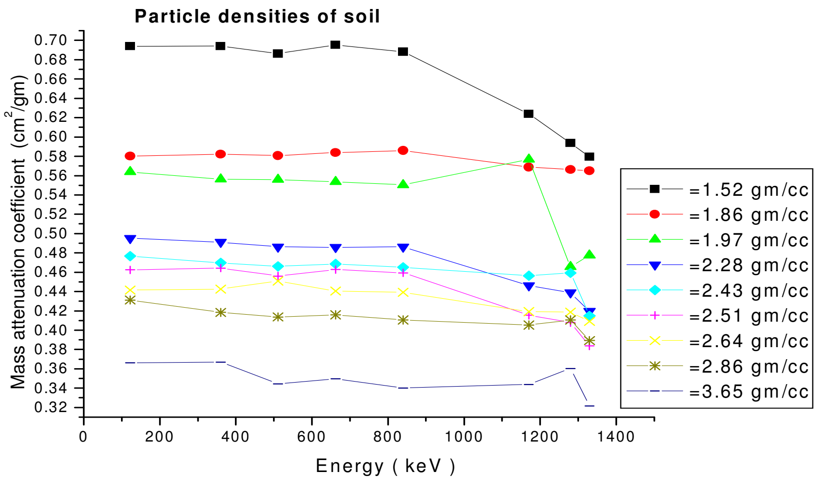

Figure 2

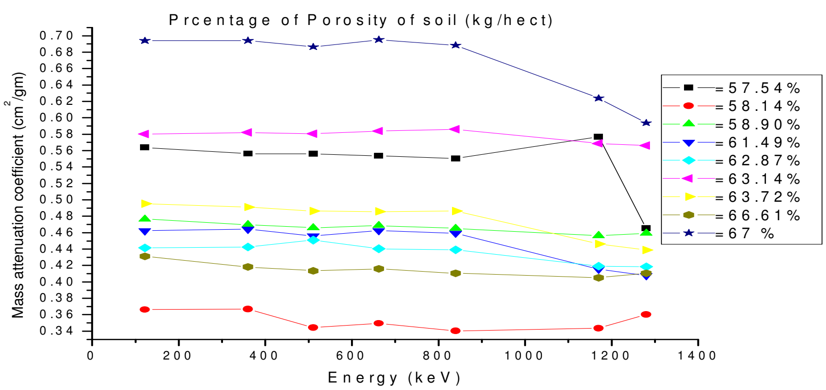

Figure 3

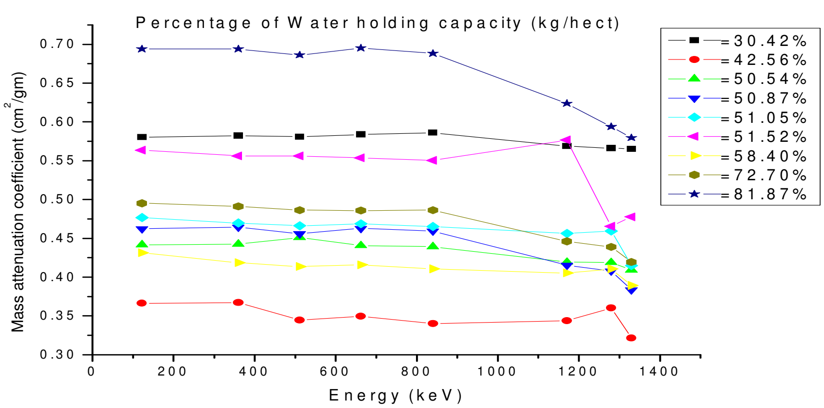

Figure 4

Conclusions

The experimental values of absorption coefficient of soil samples from Maharashtra and Karnataka at 122,360,511, 662, 840, 1170, 1280, 1330 keV have been studied. Exponential decay observed. As energy increases the mass attenuation coefficient of soil samples decreases. This gives the validity of exponential absorption law, $I = I_0 e^{-\mu x}$ where, x is thickness of the soil sample. The linear and mass attenuation coefficient depends on material density, sample composition and photon energy E.

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