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Mass Attenuation Coefficients of Soil Samples in Maharashtra State (India) by Using Gamma Energy at 0.662 MeV

D.V. Raje[1], **L.M. Chaudhari**[2]

[1]Department of Physics, Rajarshi Shahu College, Latur - 413512, (Maharashtra State), India

[2]Nuclear Physics Laboratory, Nowrosjee Wadia College, Pune - 411001 (Maharashtra State), India

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Abstract. The mass attenuation coefficients μ_s of various soil samples collected from different areas in Maharashtra State (India) have been studied by using gamma radiation at energy 0.662 MeV for different soil samples. The results have been presented in a graphical form.

The increasing linear nature of graphs of number of particles of radiation counted without absorber (I_0) per number of particles of radiation counted with absorber (I) *vs*. the thickness of absorber are fitted by the least square method. The slope of these graphs gives the value of the linear absorption coefficient. The graph of density of the soil samples *vs*. the mass attenuation coefficient shows that the mass attenuation coefficient decreases exponentially with increasing density and confirms the interaction of gamma radiations with various soil samples of various components.

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1 Introduction

The attenuation coefficient is an important parameter, which is widely used in industry, agriculture, science, and technology, *etc*. The properties characterizing the penetration and diffusion of gamma rays in composite materials such as soil are very important. Soil has chemical properties as on its compositions like C, N, S, P, Ca, Mg, Na, *etc*. and has physical properties: (i) sand, sandy clay, loam, clay loam; (ii) moistness; (iii) water holding capacity; (v) particle density; (vi) appearance density; and (vii) porosity, *etc*. in variable concentrations. Soil also contains microelements such as Cu, Fe, Mg, and Zn. The effects of different parameters on the attenuation coefficients of soils were discussed in several studies. The variation of total mass attenuation coefficients with soil composition is large below 50 keV and negligible above 300 keV up to 3 MeV [1-3].

The gamma transmission method has been extensively used to obtain nondestructive measurements of different soil parameters [4], to determine the distribution of soil water content and bulk density [5], for the measurement of photon attenuation coefficients [6], for the determination of photon attenuation coefficients of Turkish soils [7], to obtain the tables of photon mass attenuation coefficients and the mass energy absorption coefficients at 1 keV – 20 MeV for elements $Z = 1$–92 and 48 additional substances [8]. Bradly, Cunningham, Carlson, Jahagirdar, Singh *etc*. have conducted systematic studies of the attenuation coefficients from time to time [9-13]. Teli and Chaudhari have determined yhe mass attenuation coefficients of salts in the form of solutions [14-20].

The purpose of this paper is to determine linear and mass attenuation coefficient of soil samples in Maharashtra State (India) for systematic studies, which is useful for society.

The 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. The attenuation of gamma rays can be expressed as

$$I = I_0 \exp(-\mu x), \tag{1}$$

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 an 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,

$$\ln I = -\mu x + \ln I_0. \tag{2}$$

The mass absorption coefficient μ_s is defined as,

$$\mu_s = (\mu/\rho)_s \rho_s, \tag{3}$$

where $(\mu/\rho)_s$ is the mass attenuation coefficient and ρ is the density of soil sample. The attenuation coefficient is represented by the symbol μ_s and its unit is cm^{-1}.

2 Experimental Arrangement

The experimental arrangement is as shown in Figure 1. The gamma ray source ^{137}Cs having energy 0.662 MeV was used. The soil sample was kept in plastic

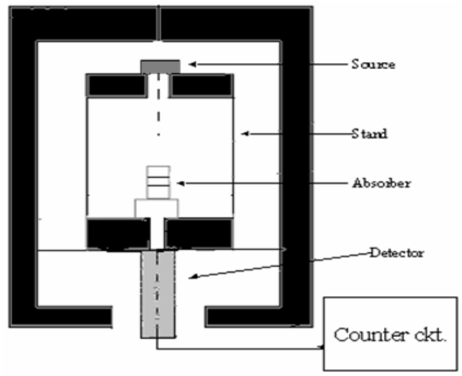

Figure 1.

container. This container was placed between gamma source and the detector with suitable geometrical arrangement. The whole system was placed in lead shielding. The detector was connected to the scintillation counter with MCA facilities, which were connected to an advanced computer system.

The readings were taken for 1800 seconds with varying the thickness of the absorber (column of the container with soil sample). The same process was used for different soil samples.

The chemical and physical properties of each soil sample are given in Table 1 (a) and (b).

Table 1. (a) Chemical components; kg/hector (percentage)

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	LATUR 1	1.25	31.17	729.39	63.82	33.61	1.51	5.88
5	LATUR 2	1.41	30.05	936.77	63.49	33.69	1.55	4.63
6	LATUR 3	0.77	28.94	912.58	49.64	46.65	2.07	6.63

(b) Physical components; kg/hector (percentage)

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	LATUR 1	41.29	11.10	58.40	2.86	66.61	44.89
5	LATUR 2	52.49	14.53	42.56	3.65	58.14	33.92
6	LATUR 3	32.44	15.01	81.67	1.52	67.00	48.71

Table 2. Percentage of microelements (in part per million)

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	LATUR 1	4.31	5.64	2.13	0.81
5	LATUR 2	2.65	5.11	2.90	0.64
6	LATUR 3	3.40	4.90	2.21	0.54

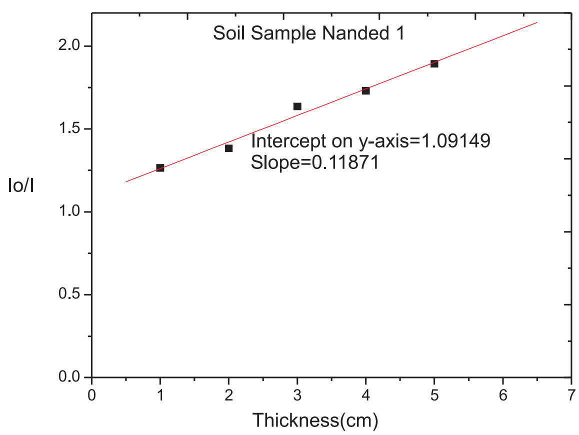

Figure 2. The thickness *vs*. I_0/I for the soil samples Nanded 1.

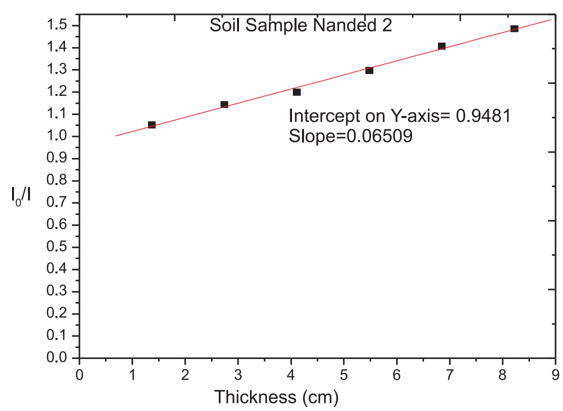

Figure 3. The thickness *vs*. I_0/I for the soil samples Nanded 2.

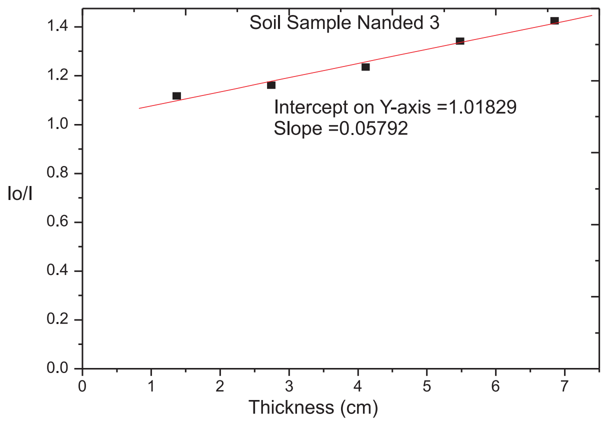

Figure 4. The thickness *vs.* I_0/I for the soil samples Nanded 3.

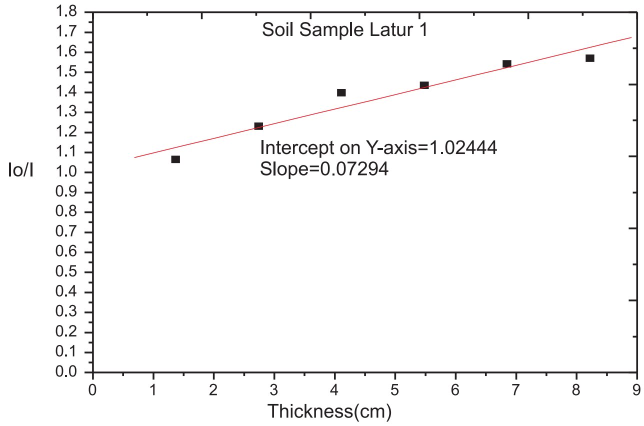

Figure 5. The thickness *vs.* I_0/I for the soil samples Latur 1.

Figures 2-7 show that the experimental values linearly increase with increasing thickness. The linear graphs are fitted by the least square method. The slopes from the above graphs give the values of linear absorption coefficients which indicate the equation,

$$\mu = m\rho_s + c, \tag{4}$$

where m is the slope, ρ_s is the density of the soil sample and c indicates the intercepts on the I_0/I axis. The other work is in progress, and it will submit the data shortly for publication in the same journal.

From Table 3 and Figure 8 it is observed that, as the density of the soil increases the mass attenuation coefficient decreases exponentially.

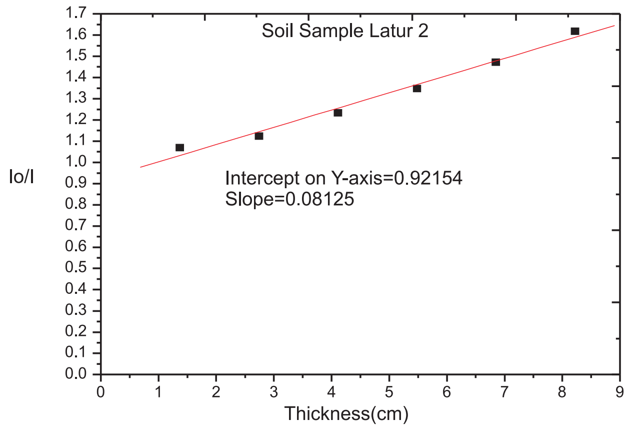

Figure 6. The thickness *vs.* I_0/I for the soil samples Latur 2.

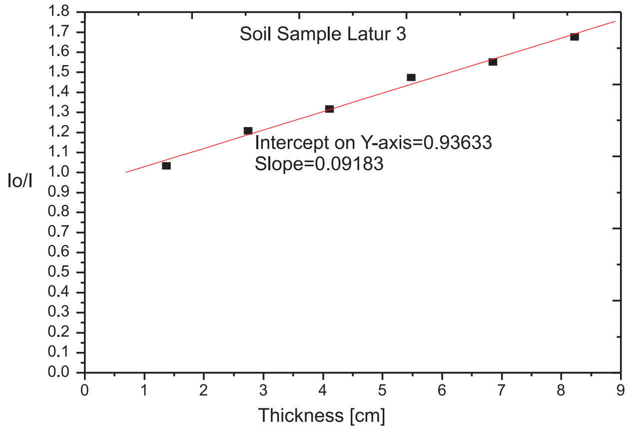

Figure 7. The thickness *vs.* I_0/I for the soil samples Latur 3.

Table 3. Linear absorption coefficient, μ for gamma gnergy of 0.662 MeV

No.	Sample	Density ρ_s (gm/cc)	Linear absorption coefficient, μ (cm^{-1})	Mass attenuation coefficient μ/ρ_s
1	NANDED 1	2.43	1.3799553	0.5678828
2	NANDED 2	2.28	1.0965052	0.4809233
3	NANDED 3	1.97	1.1323920	0.57481848
4	LATUR 1	2.86	1.2330484	0.4311358
5	LATUR 2	3.65	1.2181025	0.3337267
6	LATUR 3	1.52	1.0759116	0.7078366

3 Result and Discussion

The linear and mass attenuation coefficients were calculated for various soil samples of Maharashtra State (India) by using gamma transmission measurements. It was observed that the experimental values of number of particles of radiation counted without absorber (I_0) per number of particles of radiation counted with absorber (I) were linearly increased with increasing thickness. As density of soil increases mass attenuation coefficient decreases exponentially. This confirms the contribution of photoelectric absorption, Compton scattering and pair production to the absorption of gamma rays by the soil samples.

4 Conclusion

The mass attenuation coefficient values were measured for various soil samples at gamma energy 0.662 MeV. The mass attenuation coefficient values are useful for quantitative evaluation of interaction of gamma radiations with soil samples.

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