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Research Article

Measurement of photon attenuation coefficient of soil samples at energy 360 keV

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Abstract: The attenuation coefficient is an important role in agriculture research as well as in industry, forensic sciences etc. We measured the linear and mass attenuation coefficients of soil samples. The attenuation coefficient usually depends upon the energy of radiations and nature of the material. The result represented in graphical forms. This confirms the interaction of gamma radiations with soil sample of various components.

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

INTRODUCTION

The knowledge of interaction of gamma radiations with the materials of common and industrial use, as well as of biological and commercial importance has become major area of interest in the field of radiation science. For a scientific study of interaction of radiation with matter a proper characterization and assessment of penetration and diffusion of gamma rays in the external medium is necessary.

The mass attenuation coefficient usually depends upon the energy of radiations and nature of the material. For characterization the penetration and diffusion of gamma, radiation in any medium the role of attenuation coefficient is very important.

Hubbell[1] studied data on mass attenuation coefficients of gamma rays in compound and mixtures of dosimetric interest in the energy range of 1 kev to 20 Mev. An updated version of attenuation coefficients for elements having atomic number from 1-92 and for 48 additional substances have been compiled by Hubbell & Sheltzer [2].

Other scientists such as Bradley [3], Cunningham [4], Carlsson [5], Jahagirdar [6], Singh[7], The reports on attenuation coefficients measured by researchers reported [8-16] for different energies for various samples in solid as well as liquid. The observations have been compared with values, which have been derived from application of the mixture rule by using the values for elements (Hubbell 1982). 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 studied the absorption properties of soil sample contains mixture of microelements having physical and chemical properties

The absorption coefficient of soil is dependent on its content and gamma- ray energy. This work describes a study of content dependence on measurements of attenuation of gamma-radiation at gamma-ray energy 360keV of soil samples.

The attenuation of gamma rays expressed as:

$$I = I_o \exp(-\mu x) \qquad (1)$$

Where I_o 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 path length *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,

$$\log I = \log I_o - \mu x$$

$$\text{i.e. } \mu x = \log (I_o / I)$$

$$\text{i.e. } \mu = (1/x) \log(I_o/I) \qquad (2)$$

If we plot the graph between (I_o/I) on Y-axis and increasing thickness (i.e. path length in cm) on X-axis.The slope m and intercept on Y-axis c gives the value of the linear absorption coefficient as,

$$\mu = m \rho_s + c \qquad (3)$$

The mass absorption coefficient of Soil μ_s defined as,

$$\mu_s = \mu / \rho_s \qquad (4)$$

Where, ρ_s is the soil density and , μ_s is the mass attenuation coefficient

The unit of μ is Cm^{-1} and that of μ_s is Cm^2/gm.

EXPERIMENTAL ARRANGEMENT

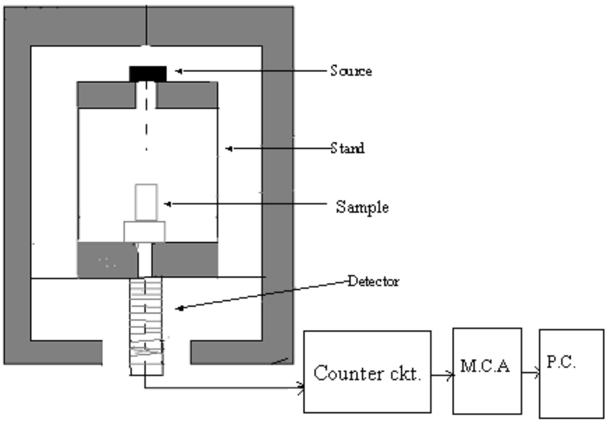

Fig.1: Experimental set up

The experimental arrangement is as shown in figure. A NaI (Tl) crystal was used as detector in conjunction with counter circuits and multichannel analyzer. The stand is made up of acrylic sheet the whole system enclosed in a lead castle. Various gamma ray sources are used to study the photon attenuation coefficient of soil samples as shown in the table 1. In this paper we are studying the attenuation coefficient for soil samples by using the gamma ray source Ba^{133} of 360 keV having nominal activity 3.14 µCi and half life 7.5 years.

Table- 1: Table of radioactive source:

Source	Energy KeV	Normal activity µCi	Half life
Ba-133	360	3.14	7.5 Years

METHOD AND OBSERVATIONS

For this work, soil samples were taken from Latur , Osmanabad and Nanded regions of Maharashtra state and Bidar from Karnataka, India. Compositions and physical properties of soil samples are identified by the cooperation of Govt. Soil Testing Office, Pune**.** Gamma rays is passed using Cs^{137} and Co^{60} reaching the detector and energy is calibrated. The spectrum of Ba^{133} of 360 keV is obtained for 1800 sec using MCA which gives graph of Channel no. V/s counts. We select the peak which is smoothened for avoiding the random nature and obtain the peak gross area.

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 Ba^{133} of 360 keV and detector, firstly the number of counts I_o of gamma particles for 1800 sec was measured to remove error due to random nature of radioactivity. Then by increasing the soil sample in container 1 cm, 2 cm, and 3 cm etc. the number of counts I of gamma particles for 1800 sec was measured for each path length. This procedure was repeated for different soils for energy360keV. For this experiment MCB1 (U1-2) software was used.

Firstly, the graphs of Thickness of soil sample (Path length) V/s. (I_o/I) for soil sample are plotted. Straight lines obtained for Gamma ray energy. Slopes and intercepts on Y- axis (c) are noted for each straight line for the calculation of linear and mass attenuation coefficients.

Finally, density vs. mass attenuation coefficient for soil sample plotted for result. The chemical and physical property of soil sample has given in **Table - 2A and Table-2B** as below:

Table- 2A:

Sr. No.	Constituents → / Soil Sample ↓	Carbon (C) %	Phosphorus (P) Kg/hect	Potash (K) Kg/hect	Calcium (Ca) %	Magnesium (Mg) %	Sodium Na %	Free Calcium-Carbonate CaCo3 %
l	Nanded1	1.39	28.38	310.04	37.50	49.16	12.71	5.25
2	Nanded2	1.04	23.93	1518.72	37.76	56.15	4.23	7.88
3	Nanded3	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	2.5
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	721.79	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- 2B:

Sr. No.	Constituents → / Soil Sample ↓	Silica (sand) %	Moistness %	Water Holding Capacity %	Soil density (gm /cc)	Porosity %
l	NANDED1	48.31	4.12	51.05	2.43	58.90
2	NANDED2	25.96	6.42	72.70	2.28	63.72
3	NANDED3	27.31	6.35	51.52	1.97	57.54
4	BIDAR 1	32.50	11.07	50.87	2.51	61.49
5	BIDAR 2	14.16	10.07	30.42	1.86	63.14
6	BIDAR 3	24.13	5.24	50.54	2.64	62.87
7	LATUR 1	41.29	11.10	58.40	2.86	66.61
8	LATUR 2	52.49	14.53	42.56	3.65	58.14
9	LATUR 3	32.54	15.01	81.67	1.52	67.00

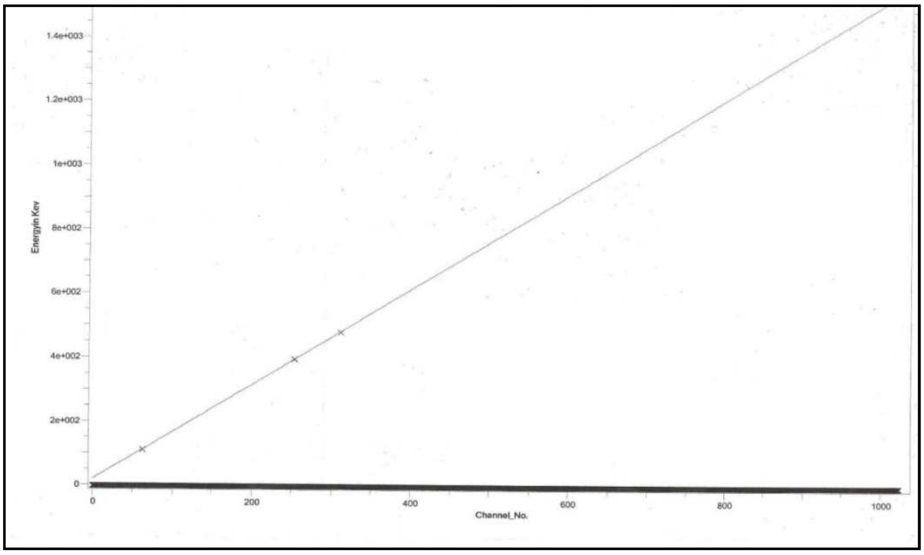

Fig. 2: Calibration Spectra

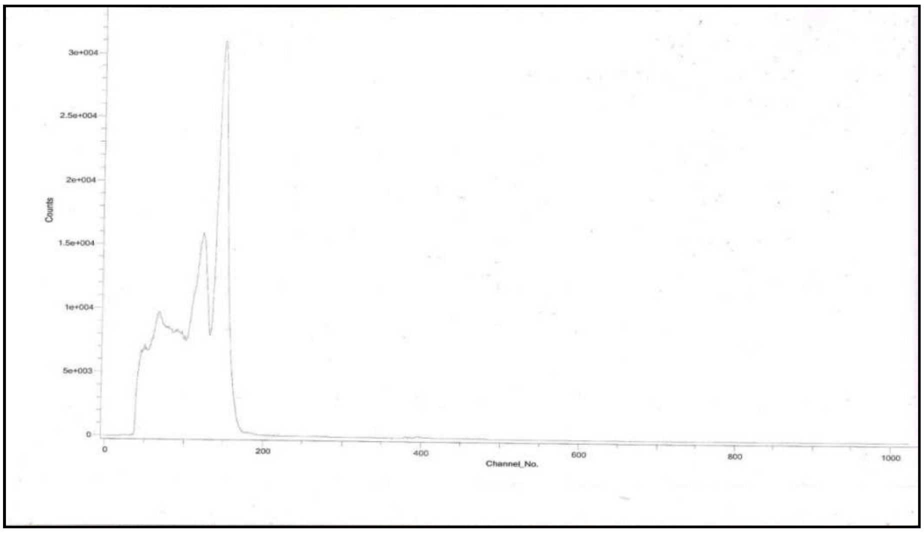

Fig. 3: Gamma ray spectra for Ba^{133}

RESULT

Experimental values of number of particles of radiation without absorber (I_o) per number of particles of radiation counted with absorber (I) were linearly increased with increasing thickness (i.e. path length in cm). The slope of these graphs gives the value of the linear absorption coefficient.

Finally, Graph of Soil density V/s Mass attenuation coefficient soil samples plotted as below. Exponential decay was observed. This gives the validity of exponential absorption law, $I = I_0 e^{-\mu x}$ where, x is thickness of the soil sample. This confirms the contribution of photoelectric absorption, Compton scattering and pair production to the absorption of gamma rays by the soil samples.

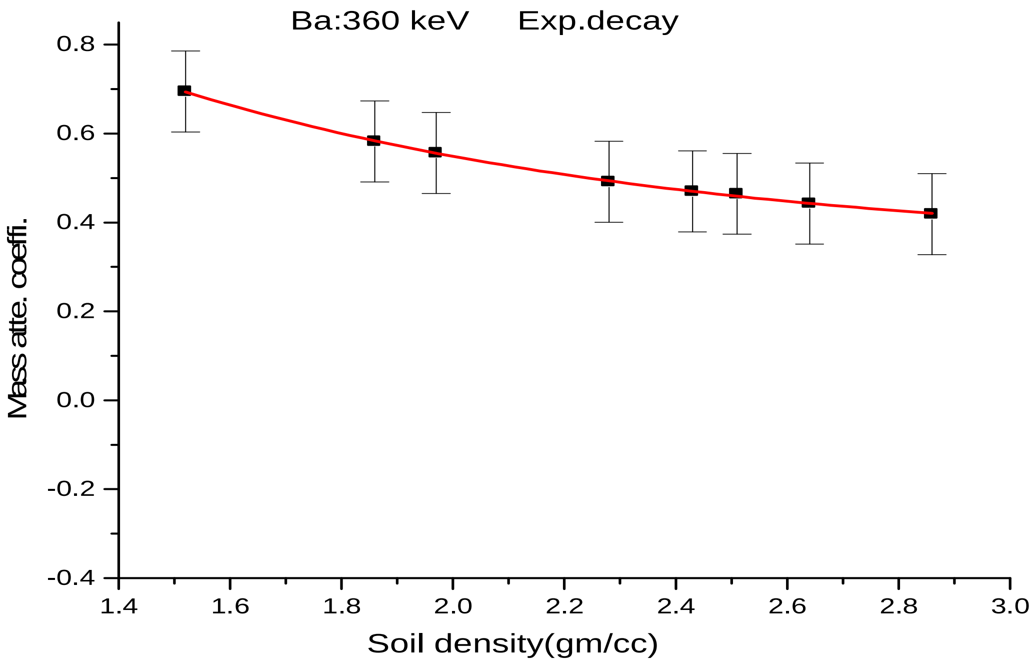

Fig. 4: Soil density versus mass attenuation coefficient

CONCLUSION

The effect of physical components like sand, moistness, water holding capacity, particle density, porosity etc. and chemical components like C, S, P, Ca, Na, Cu, Fe, Mg, Zn, $CaCO_3$, etc. on linear and mass attenuation coefficient of soil samples have been investigated at gamma ray energy 360 keV. These parameters usually depend on the energy of the radiations and composite materials of the Soil and are useful for quantitative evaluation of interaction of gamma rays with various components in the Soil samples. As density increases the mass attenuation coefficient of soil samples decreases. The mass attenuation coefficient values are useful for quantitative evaluation of interaction of gamma radiations with soil sample.

This method is useful for the study of properties the soils in agriculture purposes.

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