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Mass Attenuation Coefficient Measurements in Soil Sample

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Abstract

Mass attenuation coefficients of soil sample in Nanded District (M.S.,India) using gamma ray energies 360 to 1330 keV have been measured. The mass attenuation coefficient usually depends upon the energy of radiations and nature of the material. The result represented in the form of graph. Exponential decay was observed. This validates the gamma absorption law.

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

Introduction

The study 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 roll of attenuation coefficient is very important.

An extensive data on mass attenuation coefficients of gamma rays in compound and mixtures of dosimetric interest have been studied by Hubbel[1] 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 and 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[8-24] 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. 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 have embarked on a study of 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 energies 123, 360, 510, 662, 840, 1170, 1280 keV of soil sample from Nanded district, MS in India.

The attenuation of gamma rays expressed as:

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

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 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,

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

i.e. $\mu x= \log (I_{o/} I)$

i.e. $\mu = (1/x) \log(I_{o/}I)$ (2)

The mass absorption coefficient of Soil μ_s defined as,

$\mu_s = \mu/\rho$ (3)

Where, μ_s is the mass attenuation coefficient and ρ is the particle density of soil. The unit of μ is cm^{-1} and that of μ_s is cm^2/gm

Material and Methods

The experimental arrangement is as shown in figure. The gamma ray sources sealed in plastic pencil having nominal activity 1mCi. A NaI (Tl) crystal was used as detector in conjunction with counter circuits. The whole system enclosed in a lead castle.

Experimental Setup: The experimental setup is as shown in figure 2:

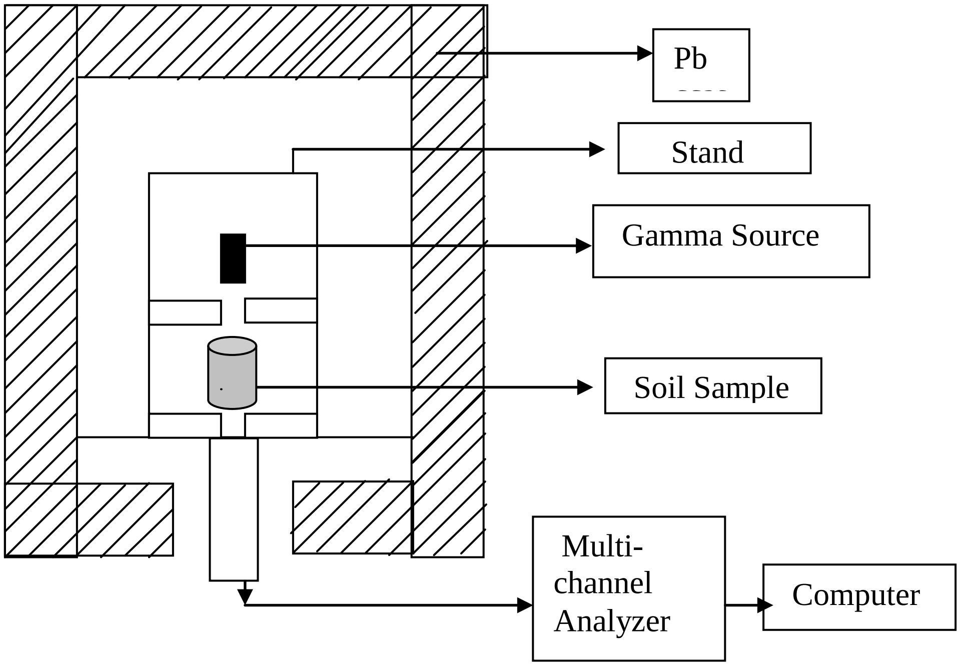

Figure - 1

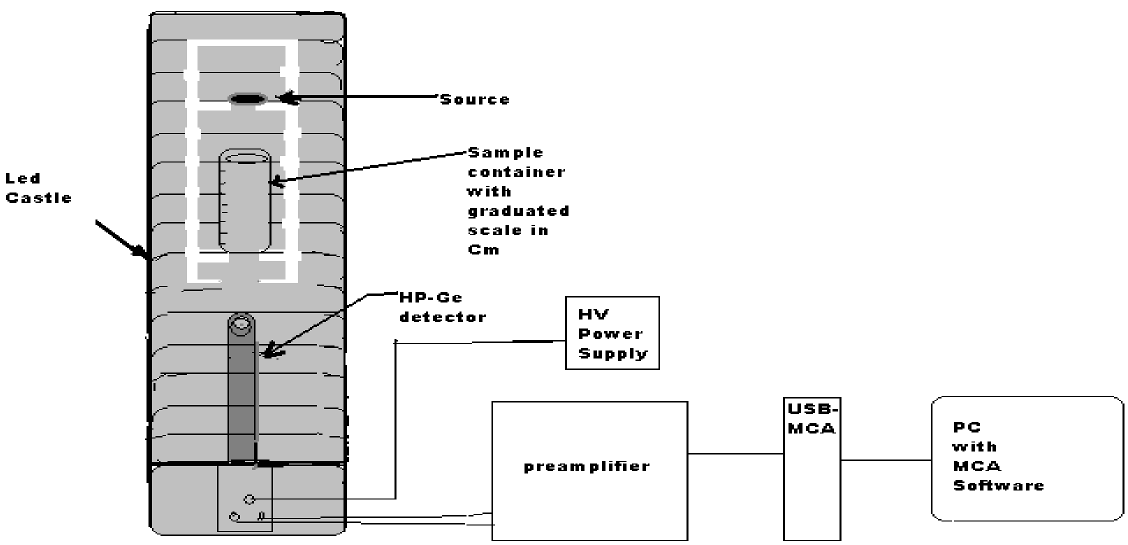

Figure -2

A cylindrical plastic container for soils of internal diameter 3.2 cm placed in between detector and source as in figure. The path length of soil for Gamma ray transmission (x) = 7 cm. Source, Cylinder kept in a stand. The assembly was placed over the detector. The distance between detector and source was 15.2 Cm. The transmitted and scattered Gamma rays were detected using USB-MCA along with external NaI(Tl) detector

First, the cylinder was kept empty keeping acquisition time 1800 sec and readings were taken for gamma rays of a particular energy and noted as Io. Thereafter, the path length(x) of soil kept 7 cm and readings taken as I. Same procedure used for each samples and various sources.

Results and Discussion

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) as shown in following graphs. The slope of these graphs gives the value of the linear absorption coefficient.

Table-1
Chemical and Physical Properties

Sr. No.	Properties	Soil Sample Contents kg/hect (Percentage)
	(A) CHEMICAL PROPERTIES	
1	pH	7.74
2	Salty(EC) (Mesa /Cm)	0.30
3	Org. Compound C%	1.39
4	Sulphur (kg/hector) S	28.38
5	Phosphorous (kg/hector) P	310.46
6	Calcium Ca%	37.50
7	Magnesium Mg%	49.16
8	Sodium Na%	12.71
9	Ca Co_3 % (Free Ca %)	5.25
	B) PHYSICAL PROPERTIES	
1	a) Sand%	48.31
	b) Sandy/loam/clay loam%	15.10
	c)Clay%	36.48
2	Moistness%	4.12
3	Water holding capacity%	51.05
4	Particle density (gm/cc)	2.43
5	Appearance of density (gm/cc)	1.41
6	Porosity	58.90
7	Increase in size%	33.43

Table-2
Soil testing report of microelements

Sr. No.	Properties	Normal percentage (PPM)	Observed percentage for soil sample (PPM)
1	Copper (Cu)	0.2	3.72
2	Iron (Fe)	4.5	4.90
3	Manganese (Mg)	2	2.12
4	Zinc (Zn)	0.65	0.62

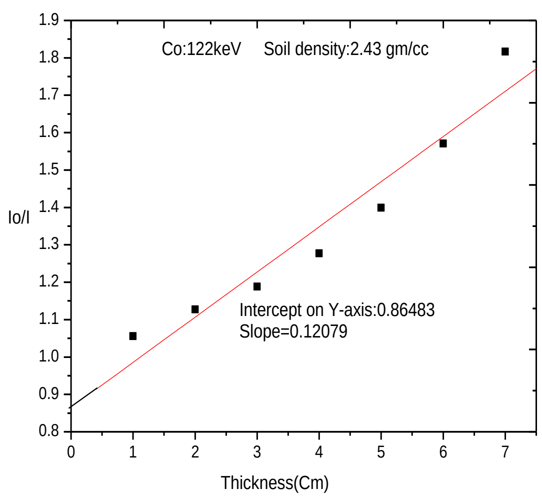

Figure –3
Thickness v/s Io/I for 123 keV

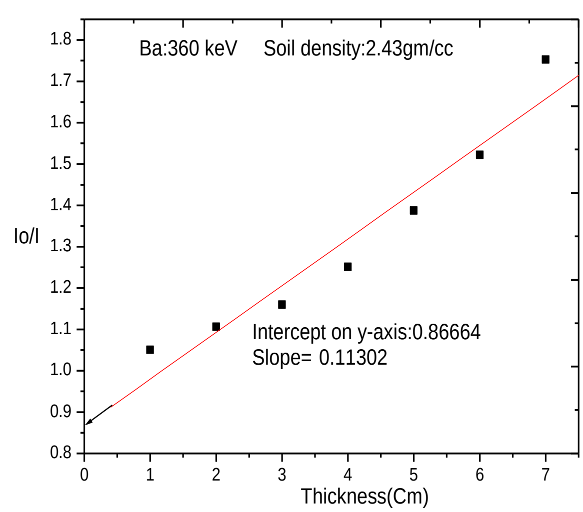

Figure- 4
Thickness v/s Io/I for 360 keV

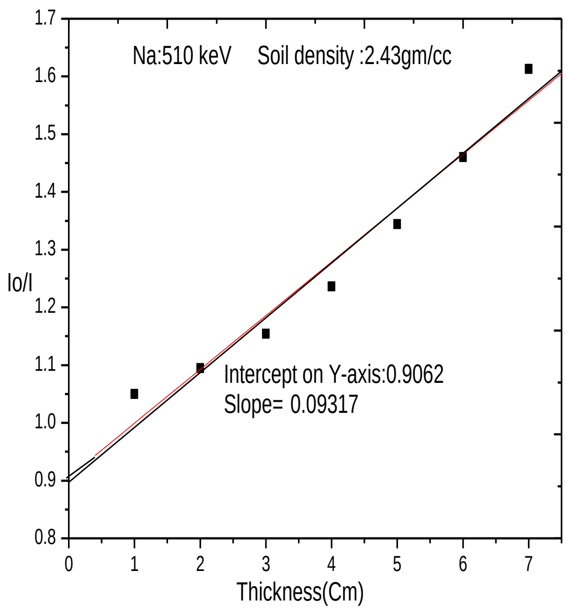

Figure-5
Thickness v/s Io/I for 510 keV

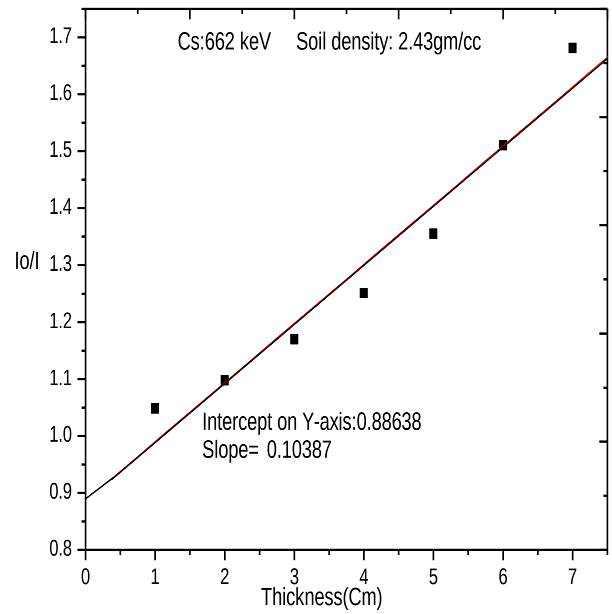

Figure -6
Thickness v/s Io/I for 662 keV

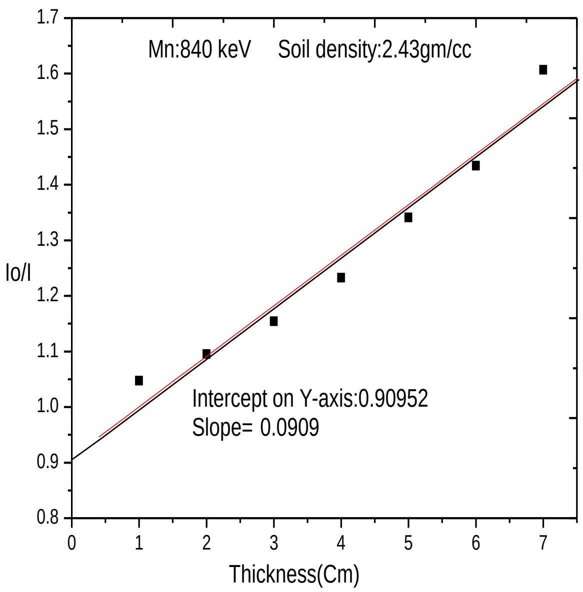

Figure-7
Thickness v/s Io/I for 840 keV

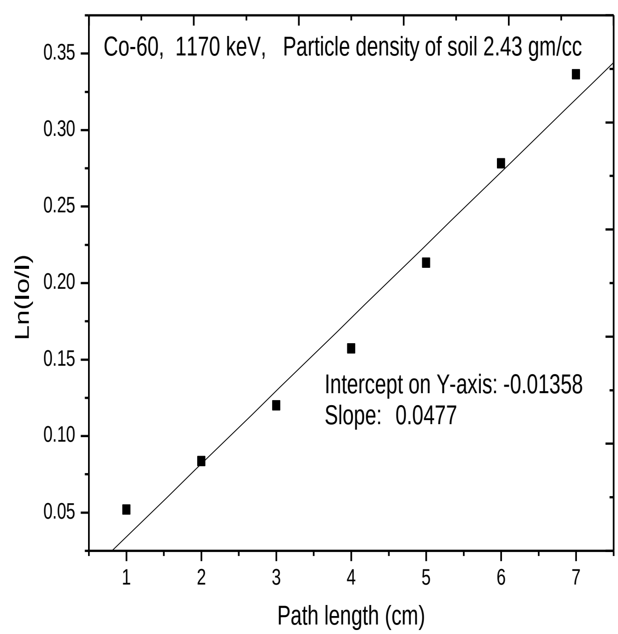

Figure-8
Thickness v/s Io/I for 1170 keV

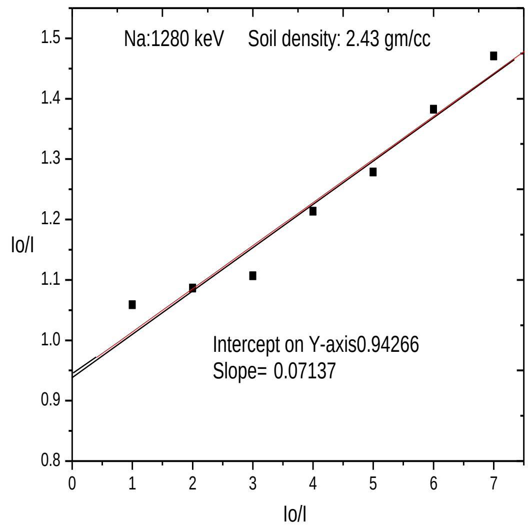

Figure-9
Thickness v/s Io/I for 1280 keV

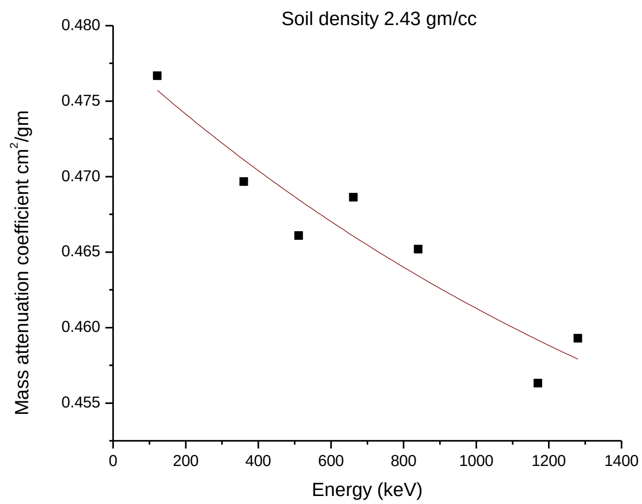

Figure -10
Energy v/s mass attenuation coefficient

Graph of energy v/s mass attenuation coefficient soil sample plotted 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.

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 eight gamma ray energies from 123 keV to 1280 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 energy 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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