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Investigation of Attenuation Coefficients of Soil samples

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Abstract

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. 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 soil sample is placed between collimated gamma source and NaI (Tl) with suitable geometric arrangement. The numbers of counts were counted with and without sample by varying the thickness of the sample. For this work, soil Samples were collected from different locations of Latur district and Osmanabad district from Maharashtra state of India and the parameters attenuation coefficients of soils were determined by performing experiment of gamma irradiation on soil samples. The results are represented in graphical forms. The Experimental measured values of linear and mass attenuation coefficient are in good agreement with standards 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 have been discussed in several studies. Soil has chemical properties dependent on its compositions like C, K, S, P, Ca, Mg, Na, etc. and has physical properties: i. Sand, Loam, Clay loam, ii. Moistness, iii. Water holding capacity, iv. Particle density, v. Appearance density vi. Porosity etc. in variable concentrations.

An extensive data on mass attenuation coefficients of gamma rays in compound and mixtures of dosimetric interest have been studied in the energy range of 1 kev to 20 Mev[1]. An updated version of attenuation coefficients for elements having atomic number from 1-92 and for 48 additional substances have been compiled[2]. The reports on attenuation coefficients for various samples in solid as well as liquid for different energies measured by researchers[3-15]. 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.

Attenuation of gamma rays: 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. The absorption of radiation characterized by the equation,

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

Where I_0 is the number of particles of radiation counted during a certain time duration without any absorber, I is intensity 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,

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

also, $$\mu = m \rho_s + c \quad (3)$$

where m is slope and c is intercept on Y-axis of each linear graphs of Thickness Vs Intensity ratio (I_o/I).

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.

Material and Methods

The experimental arrangement is as shown in figure 1. Gamma ray sources used were of energies from 122 keV to 1330 keV. The Na I(Tl) detector was used. The whole system is enclosed in a lead castle in conjunction with a counter circuit, multichannel analyzer (MCA) and "PHAST" software on a P.C. The detector absorbs a narrow beam of gamma rays after they pass through the soil sample column. A multichannel analyzer was used to analyze the detected signal.

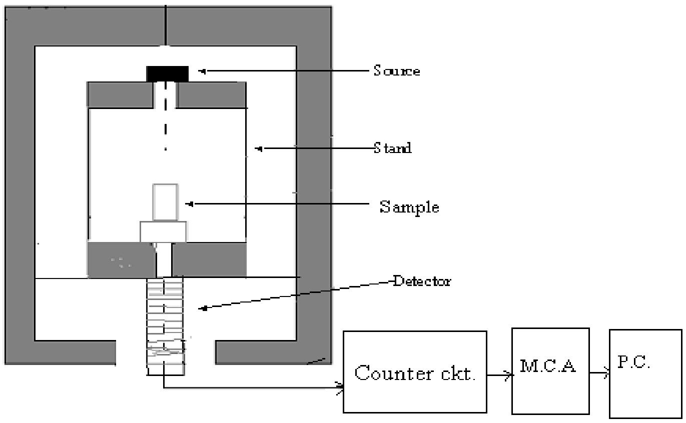

Figure-1
Experimental set up

For this work, soil samples were collected from different locations of Latur and Osmanabad districts from Maharashtra state. Figure 2 shows the locations of soil samples from Maharashtra state.

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 of height 1 cm, 2cm, etc, in the container the number of counts I of gamma radiation for 1000 sec, was measured for each path length. This procedure was 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.

Table-1
The details of radioactive sources

Source	Energy keV	Normal Activity μCi	Half life
Co-57	122	4.2	270 Days
Ba-133	360	3.14	7.5 Years
Na-22	511,1280	3.4	2.6 Years
Cs-137	662	3.26	30 Years
Mn-54	840	2	314 Days
Co-60	1170,1330	3.15	2.26 Years

Figure-2
Locations of soil samples

Table-2
Chemical compositions of soil samples

Sr. No.	Soil Sample	Carbon (C) %	Phosphorus (P) Kg/hect	Potash (K) Kg/hect	Calcium (Ca) %	Magnesium (Mg) %	Sodium (Na) %	Calcium-Carbonate ($CaCo_3$) %
1	LATUR 1	0.25	13.12	2108.10	74.13	18.19	2.58	7.00
2	LATUR 2	0.28	6.45	885.06	72.17	17.21	7.99	19.00
3	LATUR 3	0.13	13.79	325.30	73.21	23.72	1.99	3.00
4	LATUR 4	0.06	13.12	1139.60	49.15	6.69	1.67	6.75
5	LATUR 5	0.79	13.57	844.93	86.22	9.72	2.34	4.50
6	LATUR 6	0.85	13.79	1007.58	83.16	14.69	0.42	4.88
7	LATUR 7	0.25	11.34	718.19	82.65	9.31	6.63	12.50
8	LATUR 8	0.60	11.79	1219.86	64.09	27.74	5.42	11.88
9	LATUR 9	0.47	13.35	855.49	86.14	9.71	2.41	5.25
10	O'BAD 1	0.60	11.34	822.75	90.25	6.68	1.45	11.25
11	O'BAD 2	0.22	13.79	367.54	79.71	16.17	3.03	2.75
12	O'BAD 3	0.44	14.01	974.84	82.05	11.59	2.68	2.13

Table-3
Physical properties of soil samples

Sr. No.	Constituents Soil Sample	Silica (sand) %	Silt/Loam %	Clay %	Moistness %	Water Holding Capacity %	Soil density (gm /cc)	Porosity %
1	LATUR 1	33.08	23.16	43.68	7.74	68.88	2.24	64.98
2	LATUR 2	21.06	26.42	52.34	6.73	64.24	2.69	64.66
3	LATUR 3	54.56	24.76	23.49	5.38	50.72	2.67	58.37
4	LATUR 4	17.16	21.83	60.85	10.55	71.31	2.33	64.85
5	LATUR 5	7.98	22.20	69.68	10.98	32.14	2.26	63.83
6	LATUR 6	4.57	25.73	69.50	10.69	40.73	2.36	65.46
7	LATUR 7	6.16	26.97	66.65	10.09	73.13	2.54	69.72
8	LATUR 8	7.50	25.84	66.57	9.96	72.08	2.43	68.67
9	LATUR 9	18.37	37.15	55.38	10.11	68.56	2.51	66.22
10	O'BAD 1	11.82	21.87	66.21	9.36	70.07	2.34	65.84
11	O'BAD 2	18.43	27.49	53.96	6.77	63.11	2.39	61.01
12	O'BAD 3	61.09	21.46	17.36	3.41	44.55	2.62	54.28

Table-4
Table for Density Vs Mass attenuation coefficient as follows

Sr. No.	Soil density gm/cc	Mass attenuation coefficients for Energies from 122 keV to 1330 keV							
		122 KeV	360 KeV	511 KeV	662 KeV	840 KeV	1170 KeV	1280 KeV	1330 KeV
1	2.24	0.5001	0.5065	0.46969	0.47892	0.49085	0.47105	0.4766	0.46478
2	2.26	0.4949	0.5028	0.46393	0.47645	0.47243	0.468	0.46909	0.46445
3	2.33	0.4895	0.4902	0.45292	0.46662	0.48469	0.45629	0.45753	0.44256
4	2.34	0.4887	0.4859	0.45486	0.46222	0.45625	0.45441	0.46099	0.44948
5	2.36	0.4814	0.4780	0.44517	0.45968	0.4973	0.43709	0.45131	0.44366
6	2.39	0.4845	0.4846	0.44555	0.46081	0.43695	0.44649	0.45298	0.44217
7	2.43	0.4747	0.4754	0.43954	0.45432	0.43725	0.44184	0.4613	0.43292
8	2.51	0.4596	0.4624	0.42354	0.43749	0.44025	0.42579	0.4276	0.4205
9	2.54	0.4587	0.4774	0.42241	0.43338	0.42127	0.4235	0.42772	0.41602
10	2.62	0.4595	0.4581	0.4102	0.42612	0.40668	0.41173	0.41705	0.39558
11	2.67	0.4533	0.4469	0.40476	0.4167	0.43192	0.39156	0.41174	0.39849
12	2.69	0.4336	0.4431	0.40139	0.42078	0.40131	0.40364	0.40723	0.39646

Results and Discussion

Graphs of Energy in keV v/s Mass attenuation coefficient in cm²/gm of various soil densities plotted, exponential decay observed as follows:

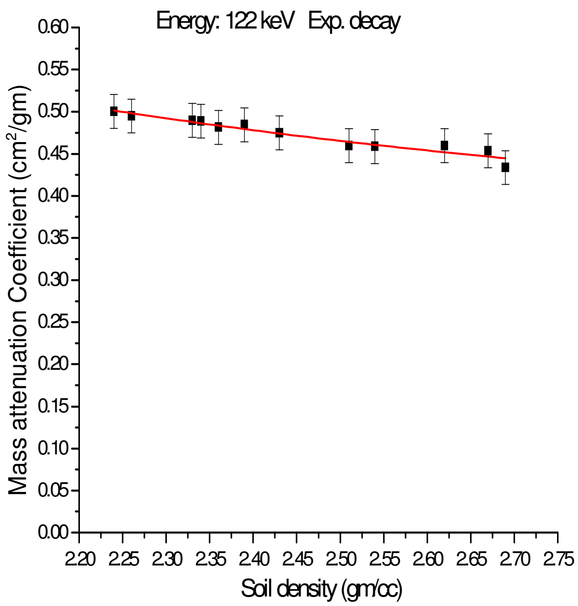

Figure-3
Soil density Vs. Mass attenuation Coefficient at 122 keV

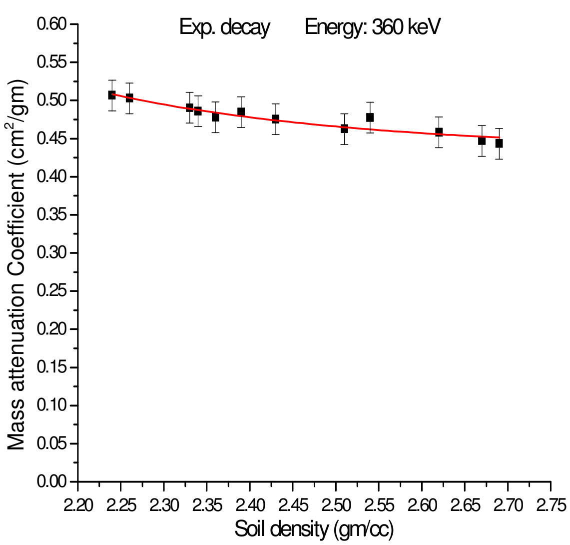

Figure- 4
Soil density Vs. Mass attenuation Coefficient at 360 keV

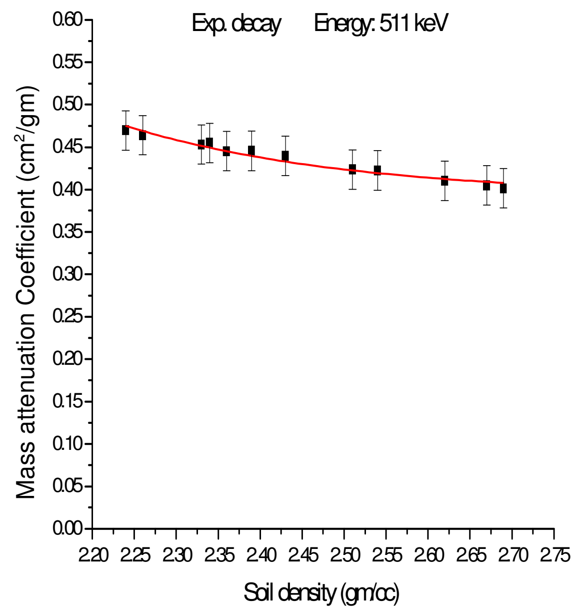

Figure-5
Soil density Vs. Mass attenuation Coefficient at 511 keV

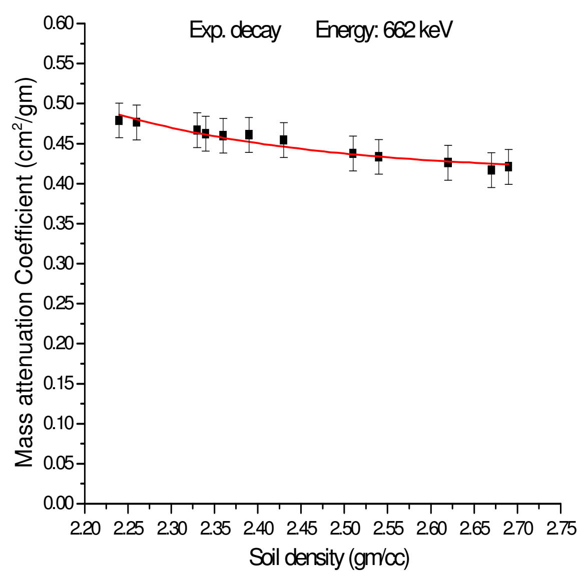

Figure-6
Soil density Vs. Mass attenuation Coefficient at 662 keV

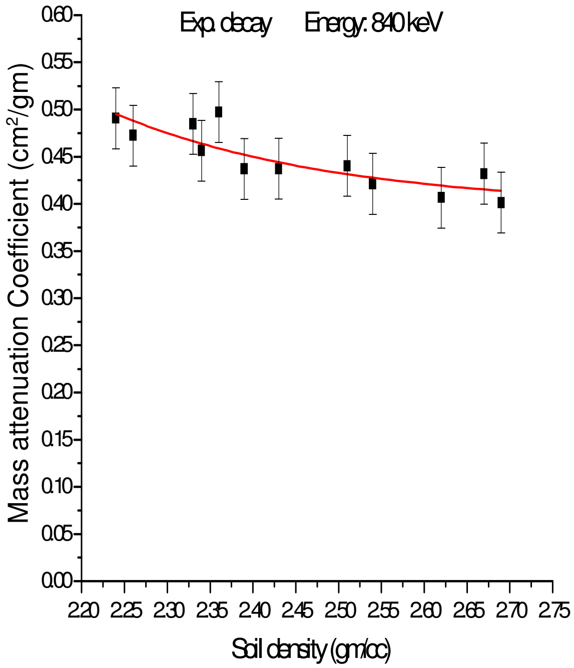

Figure-7
Soil density Vs. Mass attenuation Coefficient at 840 keV

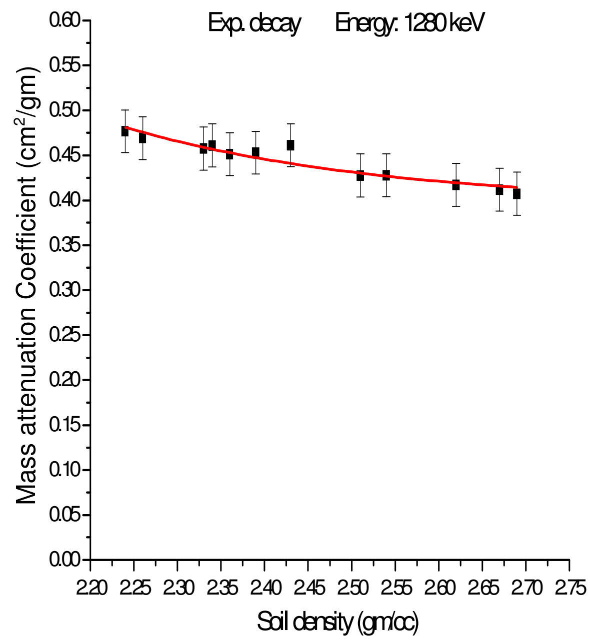

Figure-9
Soil density Vs. Mass attenuation Coefficient at 1280 keV

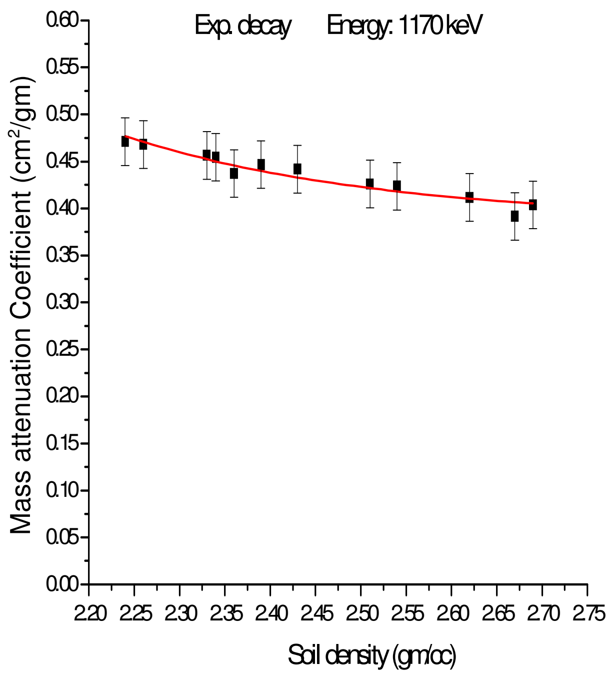

Figure-8
Soil density Vs. Mass attenuation Coefficient at 1170 keV

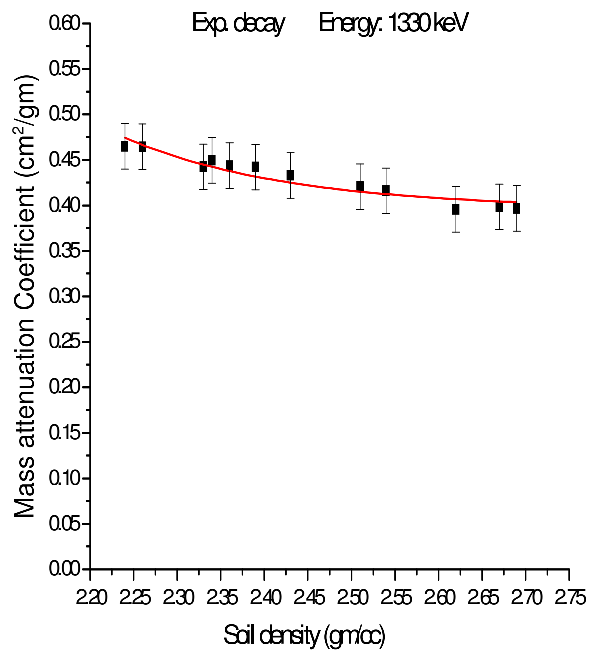

Figure-10
Soil density Vs. Mass attenuation Coefficient at 1330 keV

Conclusion

The experimental values of absorption coefficients of various soil samples from diferrent locations from Latur and Usmanabad district from Maharashtra at 122,360,511, 662, 840, 1170, 1280, 1330 keV have been studied. Exponential decay observed. As energy increases, the mass attenuation coefficient of various densities and compositions decreases. This gives the validity of exponential absorption law.

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