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DETERMINATION OF THE PHOTON ATTENUATION COEFFICIENTS FOR TURKISH SOILS BY GAMMA TRANSMISSION

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Abstract

In this study, variation of photon attenuation coefficient with chemical composition, grain diameter and water content has been investigated, using gamma-ray transmission method. For this aim, soil samples were collected from different region of Turkey and the photon attenuation coefficients of soils were determined by performing transmission experiments using a narrow beam geometry established in this study.

Introduction

The photon attenuation coefficient is an important parameter characterising the penetration and diffusion of gamma rays in composite materials such as soil [1]. Soil has a chemical composition characterised by the presence of SiO_2, Al_2O_3 and MgO in variable concentrations. 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], [2], [3]. The gamma transmission method has been extensively used to obtain nondestructive measurements of different soil parameters [4]. The purpose of this paper is to determine photon attenuation coefficient of soils and the effects of different parameters on photon attenuation coefficient by using the gamma-ray transmission technique.

Attenuation of gamma rays and experimental studies

The attenuation of gamma rays in a soil column is expressed by

$$I = I_0 \exp(-\mu_s x) \qquad (1)$$

where I_0 is the initial intensity of gamma rays and I is the intensity of gamma rays after attenuation through a soil column of length x, μ_s is the linear attenuation coefficient of the dry soil and it has unit's cm^{-1} . It can be described as

$$\mu_s = (\mu / \rho)_s \rho_s \qquad (2)$$

where $(\mu / \rho)_s$ is the mass attenuation coefficient and ρ is the physical density of dry soil. Equation (2) can be extended to wet soil as

$$\mu_{wet} = \mu_s \rho_s + \mu_w \theta_v \qquad (3)$$

where μ_w is the mass attenuation coefficient of water and θ_v is the volumetric water content (5). The experimental set-up consists of a NaI (Tl) detector and a gamma source both encased in lead as shown in Figure 1. The diameter of the columnator for the source and the detector was 5 mm. The source and the detector were mounted on a base plate. The detector absorbs a narrow beam of gamma-rays after passing through the test column. A multichannel analyser was used to count the signal magnitude of the transmitted gamma rays. A soil sample was used in a 5x5 cm cross-sectional and 25 cm length perspex column that could be moved downward and upward (6). The bottom of the column is conical in shape with the provision of an outlet hole that could be closed. The chemical composition of the soil samples considered is given in Table 1. Dry soils were passed through 0.85, 1.4 and 2-mm sieve and packed in the perspex column. In order to find the compaction of the soil column, the gamma-ray transmission measurements were taken at different depths of the column. For dry soil samples, different photon energies (316, 468 and 604 keV from Ir-192, 662 keV from Cs-137, 1173 and 1332 keV from Co-60) were used. After the gamma-ray transmission measurements were taken for dry soil at three-grain diameter, the bottom of the perspex column was closed and water was poured on the surface of the soil column with known quantities. After each irrigation the transmission measurements were repeated at different depths of the column.

Results and Discussion

The mass attenuation coefficients of soils were calculated from Equation (1) and Equation (2) for known physical densities by using gamma transmission measurements for dry soil samples. The mass attenuation coefficient values determined for different soils vs photon energies are presented in Figure 2. From Figure 2, it is seen that the mass attenuation coefficient for the different soil samples changes in a narrow range in the intermediate energy region. On the other hand, the value of mass attenuation coefficient of soils is found to decrease with increase in grain diameter as shown in Figure 3. After irrigation, the gamma transmission measurements were achieved by using Cs-137 (662 keV) gamma source. In the attenuation measurements, it is measured the total linear attenuation coefficients. Therefore the linear attenuation coefficient increases linearly with the water content as shown Figure 4.

Table 1. The chemical composition of soils

	Chemical components (%)								
Soil	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	PF
Ankara	34.25	6.83	24.1	12.2	1	0.68	1.32	1.13	16.7
Kütahya	41.15	8.38	3.64	20.91	1.6	0.27	1.42	0.34	21.16
Aybasti	63.34	13.75	7.87	0.36	0.37	0.97	1.31	0.51	9.76

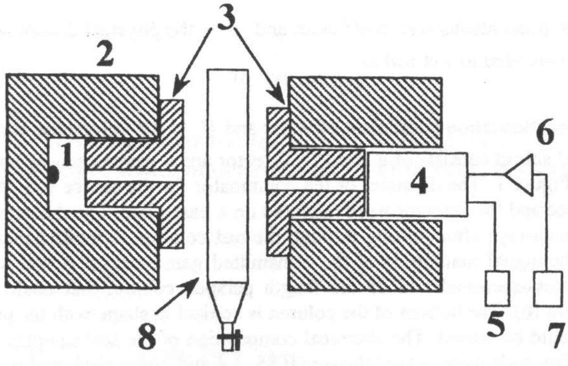

Figure 1

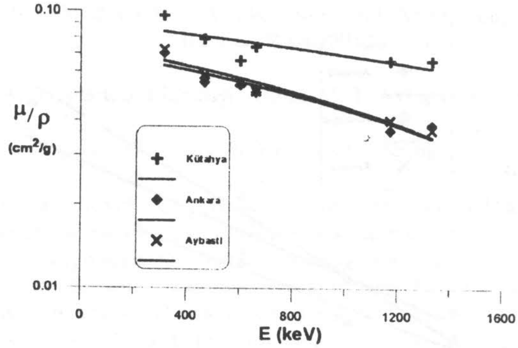

Figure 2

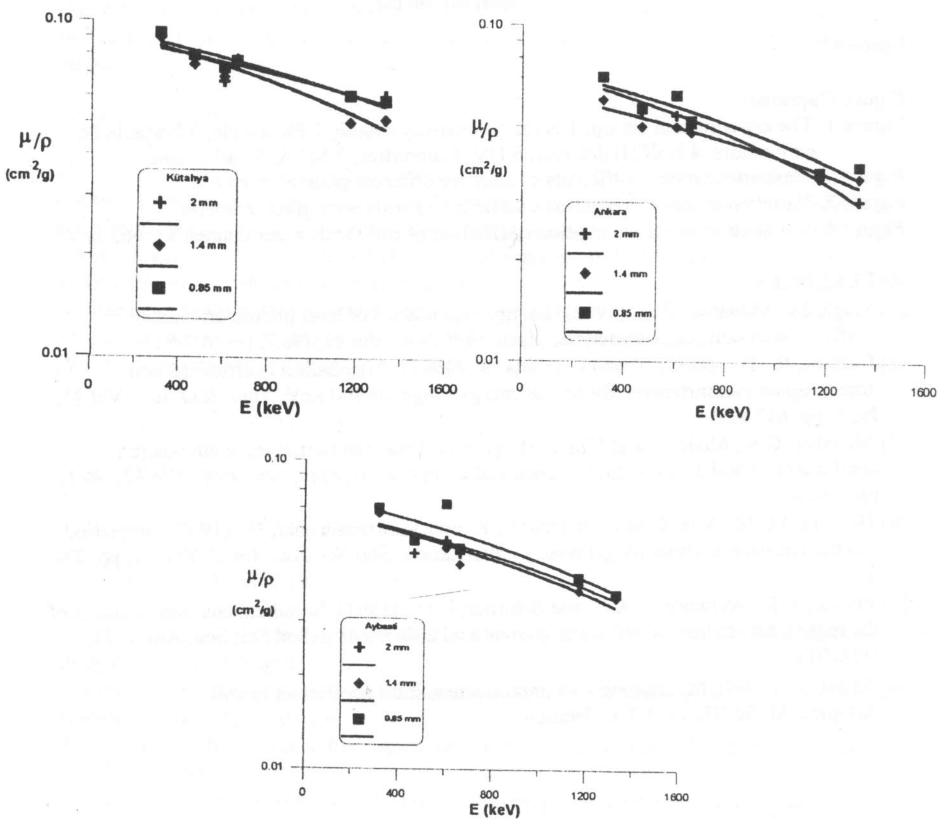

Figure 3

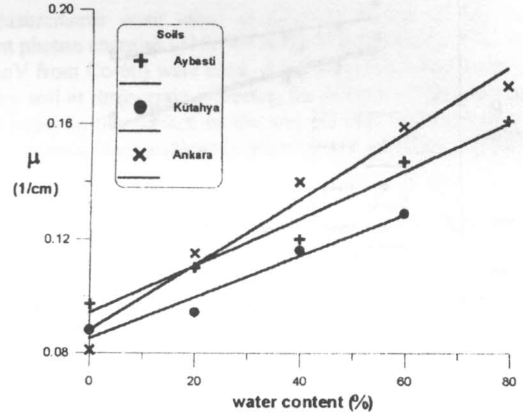

Figure 4

Figure Captions:

Figure 1. The experimental set-up; **1** is the gamma-ray source, **2** Pb shields, **3** Portable Pb collimators, **4** NaI(Tl) detector, **5** HV, **6** amplifier, **7** MCA, **8** soil column.

Figure 2. Mass attenuation coefficients of soils for different photon energy.

Figure 3. Variation of mass attenuation coefficient of soils with grain diameter.

Figure 4. Variation of linear attenuation coefficient of soils with water content for 662 keV.

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