Mass Attenuation Coefficient of Soil Samples in Kurdistan Region of Iraq by Using Gamma Energy at 0.662 MeV

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Abstract Mass attenuation coefficient of various soil samples (density ranges between 2.22 and 2.3 g cm⁻³) collected from three sites distributed in Kurdistan Region of Iraq land have been determined for gamma energy 0.662 MeV using gamma spectrometry. The average mass attenuation coefficients for the studied samples were found to be 0.0487, 0.0492 and 0.0493 cm² g⁻¹. The results have shown that Fe content of the samples has a strong effect on the mass attenuation coefficient. In general, mass attenuation coefficients determined in this study can be used for determination of gamma emitters in any soil samples.

Keywords Linear and Mass, Attenuation, Coefficients

1. Introduction

The linear attenuation coefficient also called the narrow beam attenuation coefficient, is a quantity, which specifies the ability of an absorber to reduce the intensity of gamma rays as they pass through a material such as soil due to the interactions, which faces the incident gamma rays by the soil contents [1]. The soil has chemical properties as on its chemical compositions like O, Ca, Si, Fe, Ca, Mg, K, etc. However, the variation of gamma attenuation coefficients with soil composition is negligible above 300 keV up to 3 MeV and large below 50 keV [2-4]. Several studies have been conducted on the effects of different factors on the mass attenuation coefficients of soil. For instance Hubbel (1982) has published proper values of gamma attenuation coefficients in mixtures and compounds in the energy range of 1 keV to 20 KeV. Also, the data attenuation coefficients for elements having an atomic number from 1-92 and for 48 more materials have been investigated by Hubbell and Sheltzer in 1995 [5,6]. The purpose of this study is to calculate gamma linear and mass attenuation coefficients by irradiation of soil samples of different chemical

compositions. This method is useful for the study of properties of the soils in agriculture purposes. The linear and mass attenuation coefficients of soil samples will be determined for Cs137 gamma source. In general, the attenuation of gamma rays expressed by using exponential decay law:

$$I = I_0 \exp(-\mu L) \quad (1)$$

Where I_0 is the number of particles of radiation counted during certain time without any absorber, I is the number counted during the same time with a thickness L of an absorber between the source of radiation and the detector and μ is the linear absorption coefficient.

According to Cerry and Duxbury (1998) [7]. This equation may be cast into the linear form:

$$\ln\left(\frac{I}{I_0}\right) = \ln(e^{-\mu L}) \quad (2)$$

$$\ln\frac{I}{I_0} = -\mu L \quad (3)$$

$$\ln I - \ln I_0 = -\mu L \quad (4)$$

$$\ln I = -\mu L + \ln I_0 \quad (5)$$

Where μ the slope of each linear graphs of thickness against $\ln$ (measured counts).

Furthermore, the mass absorption coefficient μ_m is defined as,

$$\mu_m = \mu/\rho \quad (6)$$

Where, μ is measured in cm⁻¹, μ_m is measured in cm²/gm and ρ is mass density of soil sample in gm/cm³ [8-13].

2. Experimental Setup

For this work, soil samples were collected from south of Erbil province, east of Koya district and west of

Chamchamal district in Kurdistan region of Iraq. The soils were in powder form, and then they pressed and converted into the pellet form with thicknesses about 1(cm). After that, the chemical composition of a soil sample from each region is identified by using X-ray Fluorescence technique (XRF) at Solid State Physics Laboratory-Koya University. Then, the whole system was setup as shown in figure (1) below:

Figure 1. Experimental setup

For this experiment, Cassy Lab software was used to record data. Firstly the background radiation was measured: the number of counts I_0 of gamma without any absorber for 600 seconds to remove error due to random nature of radioactivity. Then, a soil sample with 1(cm) thickness was put in between the detector and the gamma source as can be seen from the figure (1) for a certain time (600s) the number of counts I of gamma was measured. This step was repeated for different thicknesses of soil in each region and the soils of three mentioned regions. Furthermore, the graphs of thickness of soil sample (Path length) Versus $\ln$ (gamma intensity I) for soil samples are plotted and shown in the next sections. Finally, slopes are noted for each straight line for the calculation of linear and mass attenuation coefficients.

3. Results and Discussion

a- The chemical composition of soils in each region is given in tables below:

Table 1. Main chemical components (%mass) of the west of Chamchamal soil sample.

Elements	Mass %
O	44.5
Si	20.5
Ca	20.2
Al	6.45
Fe	3.6
Mg	2.36
K	1.18
Ti	0.455
Mn	0.0903

Table 2. Main chemical components (%mass) of the east of Koya soil sample.

Elements	Mass%
O	40.4
Si	26.8
Ca	12.7
Al	9.61
Fe	5.27
Mg	2.4
K	1.8
Ti	0.598
Mn	0.116

Table 3. Main chemical components (%mass) of the south of Erbil soil sample.

Elements	Mass%
O	44.2
Ca	20.8
Si	20.2
Al	6.30
Fe	3.70
Mg	2.75
K	1.19
Ti	0.448
Mn	0.0843

b- Thickness (cm) of soil samples versus $\ln$ measured intensity (I) of gamma rays are shown graphically as follows:

Figure 2. The thickness (cm) vs. Ln gamma intensity (counts)

Figure 3. The thickness (cm) vs. Ln gamma intensity (counts)

3. Discussion and Conclusion

From the slope of the figures (2 and 3) and according to the equation (5) it was found that the linear attenuation coefficient of soil in the east of Koya district, west of Chamchamal district and south of Erbil province are 0.1118cm^{-1} , 0.1096cm^{-1} and 0.1101cm^{-1} respectively.

Moreover, from these values and the equation (6) the mass attenuation coefficients of soil in the east of Koya district (2.2955gcm^{-3}), west of Chamchamal district (2.2258gcm^{-3}), and south of Erbil province (2.2311gcm^{-3}) are $0.0487\text{cm}^2/\text{gm}$, $0.0492\text{cm}^2/\text{gm}$, and $0.0493\text{cm}^2/\text{gm}$ respectively. It was observed that the experimental values of Ln gamma intensity counted were linearly decreased with increasing

thickness. Also, as the density of soil increases, mass attenuation coefficient decreases exponentially. This confirms the contributions of photoelectric absorption, Compton scattering and pair production to the absorption of gamma rays by the soil samples.

4. Conclusions

The effect and chemical components like C, K, S, P, Ca, Na, Mg, Cu, Fe, Zn, etc. of soil samples on linear and mass attenuation coefficient have been studied at gamma ray energy 0.662 MeV. These attenuation coefficients usually depend on the energy of the incident radiation and the composition of the soil samples. Also, it can be concluded that from the previous tables, the (Fe) content in soil has a significant effect on the values of attenuation coefficients.

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