Yadanabon University Research Journal, 2019, Vol-10, No.1

Determination of Linear Attenuation Coefficient in Soil Samples from Mandalay Region by Using Gm Counter

Yi Yi Myint*

Abstract

The main purpose of this research is to calculate the linear attenuation coefficients of three places of soil samples. The soil samples are collected from different places of Madayar Township, Maha Aung Myae Township, Pathein Gyi Township, Mandalay region. The collected samples were determined by using gamma radiation at energy 662 keV. To calculate the attenuation coefficients of soil samples, SPECTECH ST360 GM counter and ^{137}Cs gamma source were used. The results are presented in a graphical form. According to the values of the linear attenuation coefficients, the soil sample S3 is the most suitable one for the 662 keV gamma rays shielding by comparing with other soil samples.
Key words: cement samples, Geiger-Muller Counter, linear attenuation coefficients

Introduction

The attenuation coefficient is an important parameter, which is widely used in industry, agriculture, science, and technology, etc. The properties characterizing the penetration and diffusion of gamma rays in composite materials such as soil are very important. Soil has chemical properties as well as physical properties depending on compositions. Gamma-ray spectrometry is one of the most widely used techniques to determine the linear attenuation coefficient of soil samples under the same measuring conditions as those under which the system has been calibrated. In order to obtain correct results, the samples should be counted under the same measuring conditions as those under which the system has been calibrated.

Absorption of Gamma Rays

The interaction of gamma rays with matter is markedly different from charged particles such as alpha and beta particles. The most important mode of interaction between gamma radiation and matter which leads to a reduction of the gamma rays energy is that between gamma radiation and the electron of the absorbing materials. There is a long list of possible interactions of gamma rays, but only the three most important ones will be discussed here. They are the photoelectric absorption, Compton scattering and absorption by pair production.

Photoelectric Absorption

The photoelectric absorption is the complete absorption of a photon by an atom. The most likely interaction is one between the photon and the most tightly bound electron. As a result of the interaction, the Photon disappears and one of the atomic electrons is ejected as a free electron, called the photoelectron. Einstein's equation for those photoelectrons will be

$$E_{Kin} = E_r - E_k$$

Where, E_k = atomic binding energy of K – electron

E_r = energy of incoming photon

E_{kin} = kinetic energy of ejected or liberated electron

The recoiling electron has most of the energy of the incident gamma ray which is usually of the order of l MeV or greater. It loses its energy by ionization, excitation and the production of thermal energy.

* Professor and Head, Dr., Department of Physics, University of Yadanabon

Compton Scattering

It is an elastic scattering collision between a photon and an electron, during which part of the photon, energy is transferred to the electron and the original photon energy is reduced by an equal amount. Compton effect can be understood in terms of a collision of a photon with a free electron. If the gamma ray energy is sufficiently greater than the atomic binding energy of the struck electron, the latter can be considered as a 'free electron' for practical purpose. This γ-ray energy is about `0.1Mev.

From the considerations of conservation of momentum and energy, Compton's well known formula for the energy of the scattered photon in terms of the initial energy, hall and scattering angle θ is

$$h\upsilon' = \frac{h\upsilon}{1 + (1 - \cos\theta)\, h\upsilon / m_o c^2}$$

Pair Production

In pair production, a photon is destroyed and an electron and a positron are created. This can only take place in the vicinity of a nucleus to make conservation of momentum possible. This is due to the effect of conservation of radiation energy into mass energy. It results in the complete absorption of the γ-ray photon, which is converted entirely into energy of an electron pair plus a certain amount of kinetic energy.

$$h\upsilon = 2m_o C^2 + E^+_{kin} + E^-_{kin}\ ,\ h\upsilon \geq 1.022 \text{ Mev}$$

The minimum gamma energy required in creating an e^- e^+ pair is of 1.022MeV. The important fact is that the pair production process cannot occur in free space. And the kinetic energy carried away by the nucleus is negligibly small due to its large mass compared with that of the electron. Photon energy, in excess of $2m_oc^2$, is shared as kinetic energies by the product particles such as E^+_{kin} and E^-_{kin} . The three gamma interactions are illustrated in Figures 1.1, 1.2 and 1.3.

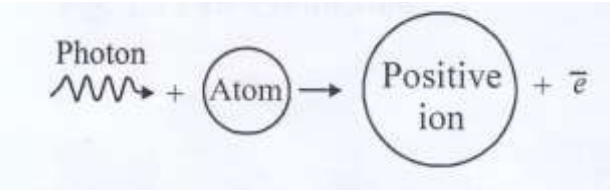

Figure 1. Photoelectric Effect

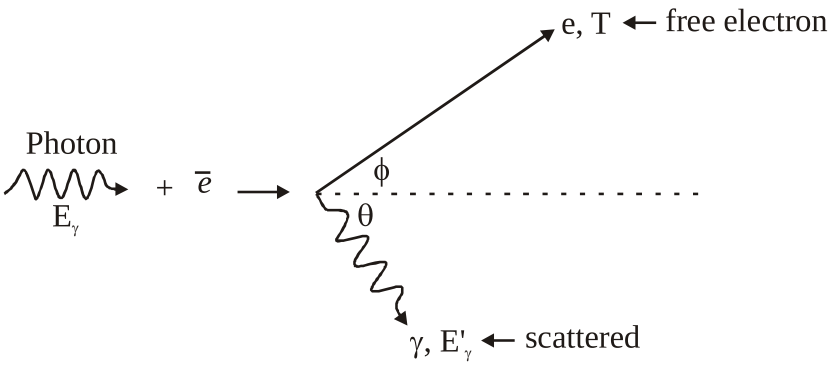

Figure 2. The Compton Effect

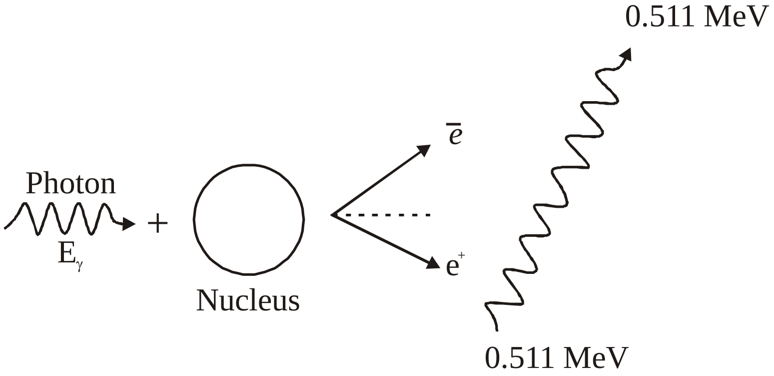

Figure 3. Pair Production

Attenuation of Gamma Rays

In gamma rays spectroscopy, one is most commonly interested only in the fraction of the monoenergetic photons that have been penetrated the layer without any interaction and therefore has their original energy and direction. The term "attenuation" refers to the remaining photons that have been either absorbed or scattered in the layer.

Linear Attenuation Coefficient

When gamma rays transverse a small thickness of matter dx at any point in a medium, the extents of the photons are proportional to the radiation intensity and the transverse thickness at that point. Consequently, in transverse the distance dx, the intensity of the gamma ray photons which have not undergone interaction will be described by

$$dI = -\mu\, Idx \qquad (1)$$

$$\frac{dI}{I} = -\mu dx$$

Where, I is the intensity, e.g., in photons per m^2 per second, and μ is the proportionality constant, usually expressed in m^{-1} unit. In is all three types of interaction of gamma ray photons with matter are included.

Each of the interaction processes removes the gamma rays photon from the beam either by absorption or by scattering away from the detector direction, and can be characterized by a fixed proper ability of occurrence per unit length in absorber. The sum of this proper ability of occurrence per unit path length that the gamma rays photon is removed from the beam.

$$\mu = \mu\ (\text{photoelectric}) + \mu\ (\text{compton}) + \mu\ (\text{pair})$$

Where, μ is called the linear attenuation coefficient of the absorber for the given radiation. If a collimated (parallel) beam of monoenergetic gamma rays of intensity I_0 passes through a thickness x of absorber, the intensity I of the emerging photons which have not suffered any interaction is obtained by integration of equation (1), the result is

$$\ln I/I_0 = -\mu x$$

$$I = I_0 \exp(-\mu x) \qquad (2)$$

where, μ = linear attenuation coefficient of the medium

I = intensity of gamma rays

I_0 = initial intensity of gamma radiation

x =thickness of absorbing material

If the thickness is expressed in cm, the linear attenuation coefficient will be given in units of cm^{-1}

$$\mu = \frac{\ln I_0/I}{x} \qquad (3)$$

Types of Radiation

Radiation is energy transmitted through space in the form of electromagnetic waves. Radiation can be divided into two groups, (i) ionization radiation (ii) non-ionization radiation. Ionization radiation comes from two sources, (i) Natural or background radiation (ii) Man-made radiation. Ionization radiation consists of electromagnetic waves that are energetic enough to detach electrons from atoms or molecules. Ionizing radiation comes from radioactive materials, X-ray tubes, particle accelerators and is present in the environment. The energy of non-ionizing radiation is less and instead of producing charged ions when passing through matter, the electromagnetic radiation has only sufficient energy to change the rotational, vibrational or electronic valence configurations of molecules and atoms. The effect of non-ionizing forms of radiation on living tissue has only recently been studied. Nevertheless, different biological effects are observed for different types of non-ionizing radiation. Both ionizing and non-ionizing radiation can be harmful to organisms and can result in changes in the natural environment.

Gamma Radiation

Gamma radiation is one of the three types of natural radioactivity. Gamma rays are electromagnetic radiation. The other two types of natural radioactivity are alpha and beta radiation. Gamma rays are the most energetic form of electromagnetic radiation, with a very short wavelength of less than one-tenth of a nanometer. Gamma radiation is very high-energy ionizing radiation and the most penetrating one. Gamma photon has no mass and no electrical charge. Gamma rays can travel much farther than alpha or beta particles. Gamma rays are emitted from the nucleus of some unstable and no electrical charge. Gamma rays can travel much farther than alpha or beta particles. Gamma rays are emitted from the nucleus of some unstable (radioactive) atoms. Rather than emit another beta or alpha particle, this energy is lost by emitting a pulse of electromagnetic radiation called a gamma ray. The gamma ray and light or microwaves are identical in nature. In gamma decay, a nucleus going moving from an excited state is related in the from of a photon. Gamma decay is represented by three effects, (i) photoelectric effect (ii) Compton effect (iii) pair production effect. In pair production, the gamma disappears and a positron-electron pair is created. Two 0.511 MeV photons are produced when the positron annihilates.

Cesium-137 Source

Cesium-137 has a half-life of 30.1 years and decays with the emission of a monoenergetic gamma ray of 1 MeV. Cesium-137 is widely used throughout the construction industry for level, moisture, and thickness gauging applications. Cesium-137 is used in the measurement of glass, plastic and rubber. Cesium and detector are placed on opposite sides of the material to be measured. Gamma radiation transmitted through the sample is then directed related to the sample thickness. Cesium is a metal that may be stable (non-radioactive) or unstable (radioactive). Non radioactive cesium occurs naturally in various minerals. Radioactive cesium-137 is produced when uranium and plutonium absorb neutrons and undergo fission. The most common radioactive form of cesium is cesium-137. It is also very useful in industry for its strong radioactivity. Cesium-137 is one of the more well-known fission products. It decays by emission of a beta particle and gamma rays to barium.

Geiger-Muller Counter

Geiger-Muller counters are very useful because their operation is simple and they provide a very strong signal, so strong that the pre-amplifier is not necessary. Geiger-Muller counter is constructed and operates on the principle of ionization due to radiation. They can be used with any kind of ionizing radiation. The Geiger-Muller counter has a built-in Geiger-

Muller tube, sensitive to alpha, beta and gamma radiation and is designed especially for automatic measurements of radioactive radiation. The disadvantage of Geiger-Muller counter is that their signal is independent of the particle type and its energy. Geiger-Muller counter provides information only about the number of particles.

Experimental Setup and Procedure

Sample Collection and Preparation

Three soil samples are collected from different places of Madayar Township, Maha Aung Myae Township, Pathein Gyi Township, Mandalay region. There are three different places of soil samples; soil sample from the farm (S1), soil sample from the garden (Maha Aung Myae) (S2) and soil sample from the garden (Pathein Gyi) (S3). Each sample is cleaned by removing unwanted material by meshes and ground to get power. Then, each sample is sieved with 120 meshes (0.21mm).

Experimental Procedure

SPECTECH ST360 GM counter is set up and the GM tube is set up. ^{137}Cs source is placed 9cm from the GM tube and the soil samples are placed in a container and then this container is placed between the source and GM tube. The working voltage is set up for 900V and the counting time is 300s. The experimental set up and the detection system of GM counter is shown in Figure 4.

Calculation of the Linear Attenuation Coefficient

The linear attenuation coefficient (μ) were determined by measuring the transmission of gamma rays through targets of three different thicknesses (1cm, 2cm and 3cm) and the gamma rays were obtained from ^{137}Cs source which emit photon of 662 keV. The linear attenuation coefficient (μ) was obtained by the absorption equation

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

Where, μ = linear attenuation coefficient of the medium

I = intensity of gamma rays

I_0= initial intensity of gamma radiation

x = thickness of absorbing material

If the thickness is expressed in cm, the linear attenuation coefficient will be given in units of cm^{-1}

$$\mu = \frac{ln\, I_0/I}{x} \quad (2)$$

Figure 4. Experimental set up of GM counter

Yadanabon University Research Journal, 2019, Vol-10, No.1

Results and Discussions

Results

The experiment was performed at the Nuclear Laboratory, Department of Physics, University of Yadanabon. Counting time for each sample is 300s. The relation between intensity ratio and various thickness of soil samples for gamma source ^{137}Cs (662 keV) are shown in Table 1. The relation between intensity ratio and thickness for different kind of soil samples are shown in Figure 5. The results of linear attenuation coefficients were calculated by using Equation 2. The results of linear attenuation coefficients are presented in Table 2.

Discussions

According to Table 1 and Figure 5, the intensity ratio of 3cm thickness of soil sample S3 is lower than the other thicknesses.
According to Table 1 and Figure 5, the intensity ratio of gamma rays versus various thicknesses of soil samples S1, S2 and S3 are nearly the same for gamma radiation.
According to Table 2, the value of the linear attenuation coefficient of soil sample S3 is greater than that of the other soil samples for ^{137}Cs source.

Table 1 The intensity ratio Vs various thickness of soil samples for ^{137}Cs (662keV)

Samples	Thickness	Net Count Rate(cps)	Ln(I/Io)
S1	1	1603	-2.9779
	2	1470	-3.0658
	3	1297	-3.1909
S2	1	1578	-2.9949
	2	1438	-3.0878
	3	1272	-3.2104
S3	1	1524	-3.0297
	2	1391	-3.1210
	3	1219	-3.2530

Table 2 The results of linear attenuation coefficient of all samples

Sample	Thickness	^{137}Cs
	X(cm)	μ(cm^{-1})
S1	3	1.0636
S2	3	1.0701
S3	3	1.0843

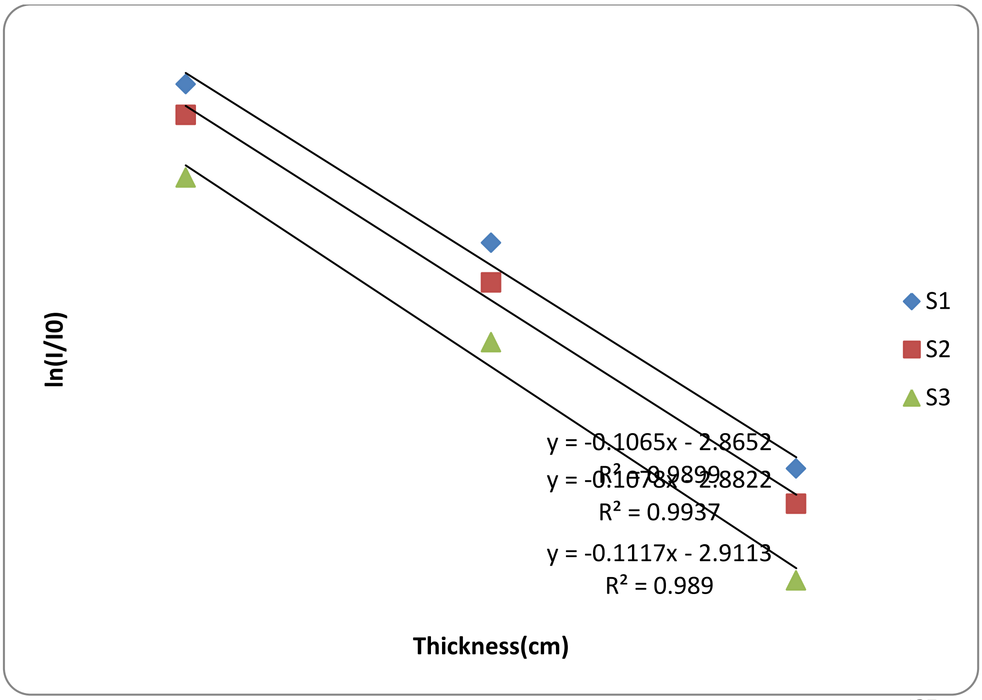

Figure 5. The intensity ratio Vs various thickness of soil samples for ^{137}Cs (662 keV)

Conclusion

In practical attenuation coefficient calculations, we are usually concerned with the attenuation of gamma radiation in geometrical configuration that is more complex. The basic dependence of radiation intensity on absorber thickness is still of an exponential character. According to the values of the linear attenuation coefficients, the soil sample S3 is the most suitable for the 662 keV gamma rays shielding by comparing with the other soil samples.

Acknowledgements

I am deeply grateful to Dr Maung Maungg Naing, Rector, University of Yadanabon, for his permission and encouragement to conduct this research.

References

[1] "Mass Attenuation Coefficients of Soil Samples in Maharashtra State by Using Gamma Energy at 0.662 MeV", D.V. Raje, India, Phys. **37**(2010).

[2] G. F. Knoll, "Radiation Detection and Measurement", John Wiley & Sons, New York, (1979).

[3] W.R. Leo, "Techniques for Nuclear and Particle Physics Experiments",Springer-Verlag, Germany (1994).

[4] N. Tsoulfanidis, "Measurement and Detection of Radiation", University of Missouri-Rolla, Taylor & Francis, Section Edition, USA (1995).

[5] "Geiger Mueller tube theory", http://www.centronic.co.uk/ downloads/ geiger-tube-theory.pdf.