ISSN:2321-1156

International Journal of Innovative Research in Technology & Science(IJIRTS)

Gamma Attenuation Coefficient of Carbonate Rocks Sampled from the North Western Coast of Egypt

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Abstract

Gamma attenuation coefficients of host rocks belonging to Moghra Formation of Eocene era in one of two candidate sites located at the North Western Coast of Egypt in Al-Dabaa locality were estimated using Monte- Carlo-Neutron-Particle Transport Code (MCNP) .Carbonates rock samples were taken to represent several depth intervals. A virtual mono-energetic gamma source with increasing energies was used. The gamma attenuation properties were found to be totally independent on the lithology of rock type, provided that rock sample density remains constant. Ultimately it is found that, gamma attenuation coefficient showed an inverse exponential dependence on the gamma energy regardless rock type, densities and their related depths.

Introduction

The main objective of this study was to significantly improve the knowledge of the local rock attenuation characteristics using Monte- Carlo-Neutron-Particle Transport Code (MCNP) tools allowing better understanding of nuclear safety including possible waste disposal/storage of low level radioactive materials inside the different layers and compartments, as well as boundary conditions. This implies to decipher all elements related to eco-system and of which water-rock interaction and processes leading to the observed mineralization.

A. Case study

The North Western coast of Egypt contains a variety of sediments. Al-Almein Quadrangle include in its periphery area Al-Dabaa site dedicated for the near future nuclear power plant.The present study aims at investigating whether the attenuation characteristics of host rock is appropriate for disposing and/or storing low level waste resulted from many sources of which nuclear waste may constitute a considerable part. Accordingly gamma attenuation coefficient of the rocks constituting the soil of the region is a key issue for nuclear safety point of view [1].Rock samples were taken from Moghra and Marmarica Formations belonging to Miocene Era as shown in Figure.1.Host rocks samples have represented 6m and 30m depth respectively. The west coast of Egypt is mainly composed of pure oolitic carbonate ([2],[3] and [4]). The oolitic grains constitute an average of 78% and 89% of the bottom and beach sediments, respectively.

B. Theoretical Background of Monte-Carlo Neutron Transport Code(MCNP)

Gamma-ray attenuation is known to depend mainly on density of material rather than its composition. Physical examination of the rocks taken from carbonate rocks of Moghra Formation at different depths in North West coast of Egypt showed that all rocks up to depth of 30 m have the same physical density, despite that chemical analysis demonstrated some change of chemical structure.

MCNP code was used to verify that attenuation coefficient will not be different for rocks from different depth in the north west coast of Egypt, given they have almost equal physical densities.

The attenuation of gamma rays passing through a length x in shield of linear attenuation coefficient μ can be expressed by the attenuation equation (1) [5]

$$I = I_o e^{-\mu x} \tag{1}$$

Where:

I_o is the gamma beam intensity incident on the shield,
I the intensity of the emergent gamma beam from the shield (or attenuated beam), μ (cm^{-1}) is the linear attenuation coefficient of the shield material, and x (cm) the mean path length of a gamma-ray in the shield.

The value of μ can be calculated directly from this equation if the intensities of the incident beam and emerging beam, and thickness of the shield were known. MCNP served in calculations. The shield geometry and thickness is chosen on demand. The intensity of the incident and the emerging beams are calculated using MCNP when a specified gamma source is present in front of the shield.

The ultimate aim of this study was to calculate gamma attenuation properties of rocks from different depths in North West coast of Egypt. MCNP was used in calculation. A virtual mono-energetic gamma source with increasing energies was used to investigate the gamma attenuation coefficient as a function of the gamma energy. The gamma

ISSN:2321-1156

International Journal of Innovative Research in Technology & Science(IJIRTS)

attenuation coefficient was found independent on the type of rock, given the density is almost equal [5]. However, it showed inverse exponential dependence on the gamma energy.

C. Methodologies and Techniques

Rocks samples belonging to Marmarica and Moghra Formations of Miocene age were taken to represent Al-Dabaa locality (North Western Coast of Egypt) at a depth 6m and 30m from ground surface , were used to shield Gamma photons emitted by a virtual mono-energetic isotropic point source. The geometry of rock samples considered is a 5.0 cm thick spherical shield of the rock material, with the gamma source at its center, as shown in Figure 2.Rock samples corresponding to the foregoing depths; 6 and 30 m respectively were also analyzed for major chemical compositions and expressed in terms of oxides(Table 1) as well as major elements (Table 2).

Results and Discussion

A. Chemical characteristics of sampled rocks

The chemical composition of the sampled rocks show dominance of calcium oxides (56%) followed by carbon dioxides (43%) by weight of the total samples and trace concentration of Aluminum oxides (0.5%) and Silicon oxides(0.5%) and to a less extent Magnesium,Potassium and sodium oxides that amount to 0.056% for each one of them. As far as the chemical elements are concerned, Oxygen constitutes the most dominant element (48%) followed by Calcium(40%) and to a less extent Carbon constitutes 11%.Trace concentration is expressed as Aluminum (0.26%) followed by Silicon (0.23%) whereas Sodium and Magnesium have constituted about 0.04 and 0.03% respectively. Higher concentration of Sodium ,Magnesium ,Aluminum and Silicon are found at samples taken from 30 m depth interval compared to samples taken from 6 m depth interval, a situation which in turn, reflects a fact of dissolution and /or ion exchange phenomena as an active rock-water interaction processes. The petrographic analysis of the sampled rock fragment examined under the scanning electron microscope has shown a dominance of calcite mineral with cementing ground of calcium carbonates (Figure 3)

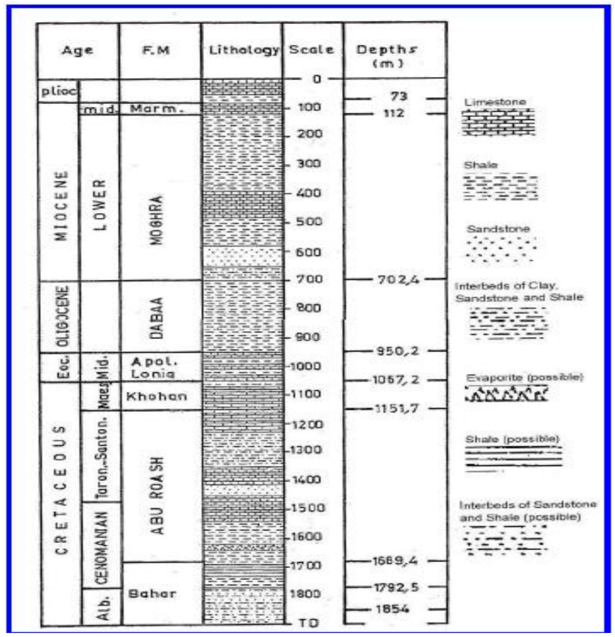

Figure 1. Litho-stratigraphic sequence of the sampled zone, North-Western Coast, Egypt.

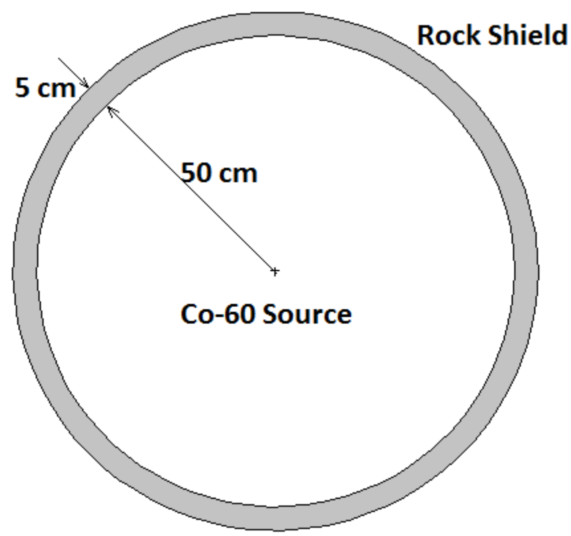

Figure 2. Geometry of Rock sample with the MCNP model

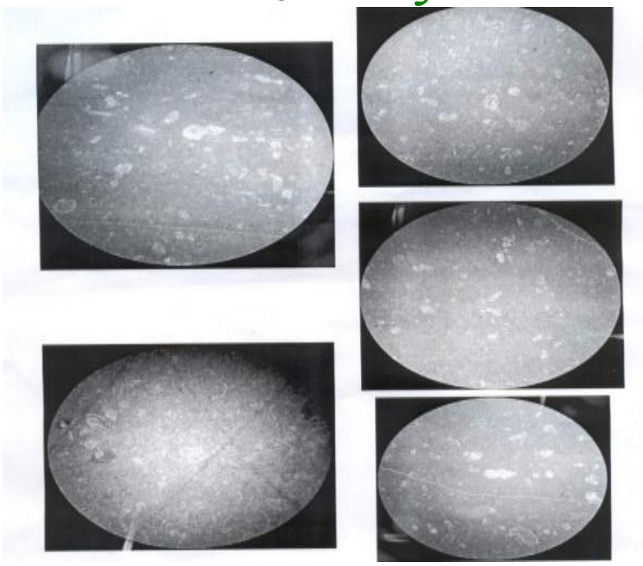

Figure 3 .Petrography of Sampled Rocks

Table 1. Chemical composition of sampled rocks expressed as oxides

Depth	CaO	CO_2	Al_2O_3	SiO_2	MgO
6 m	56.00	43.4	0.5%	0.5%	0.056%
30 m	51.6%	40.6 %	3%	3%	0.57%

Table 2. Chemical composition of sampled rock expressed as native elements .

Element $^{w}/_{o}$	C	O	Na	Mg	Al	Si	K	Ca	Fe
6 m	11.85	48.14	0.04	0.03	0.26	0.23	0.04	40.02	0.08
30 m	11.08	47.75	0.42	0.34	1.58	1.40	0.47	36.93	--

B. Petrographic characteristics of sampled rocks

The petrographic analysis of the sampled rock fragment examined under the scanning electron microscope has shown a dominance of calcite mineral with cementing ground of calcium carbonates (Figure 3).

C. Physical and geophysical characteristics of sampled rocks

Physical densities of the sampled rocks as measured were: 2.0 and 2.1 g/cm^3 for the 6 and 30 meters depth intervals respectively. other characteristics such as torque, rotation and energy for drilling machine are shown as Figure 4

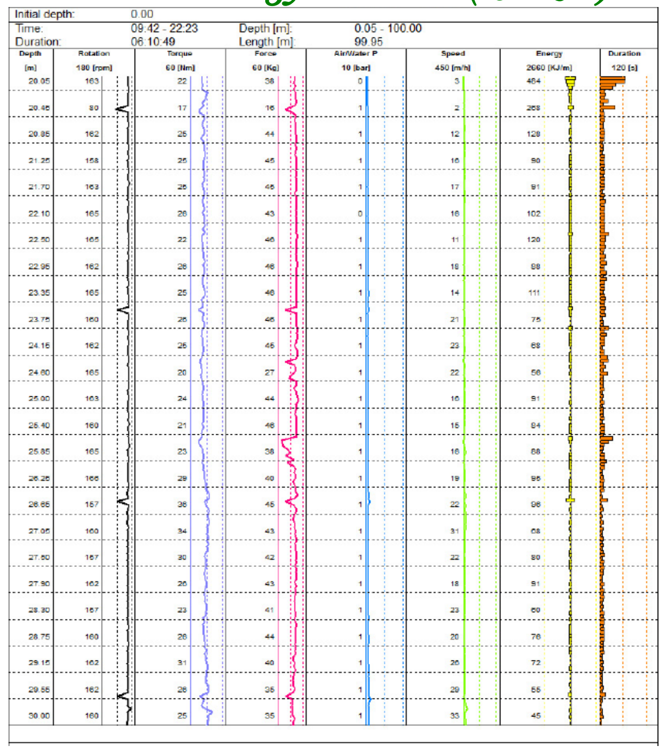

Figure 4 .Physical and Geophysical well log characteristics of sampled zone

D. Attenuation characteristics of sampled rocks

Dose attenuation coefficient of the sampled rock (5 cm thick shield) are shown as Figure 5, Figure 6 and Figure 7. There was almost no difference between gamma attenuation coefficients of the rocks from 6 and 30 meters depth. This is expected since they have almost equal physical densities. Gamma attenuation coefficients for both samples changed as inverse exponential function of gamma energy.

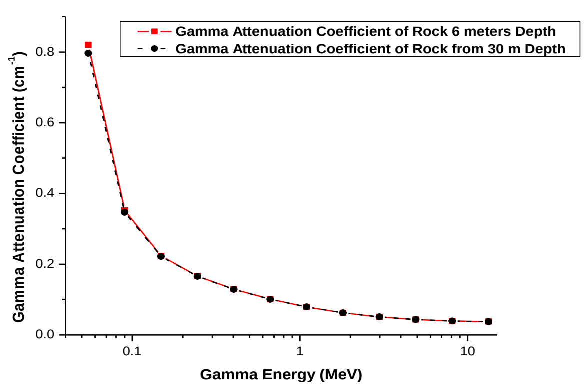

Figure 5. The calculated gamma attenuation coefficient.

As shown by Figure 5 .The binary relation between Gamma energy and Half –value thickness attains a logarithmic relationship whereas in Figure 6 , “Tenth-Value Thickness” is the thickness required for reducing the intensity of radiation by a factor of 10 for rock samples taken at different depth intervals of 6 and 30m from ground surface according to equation (2)

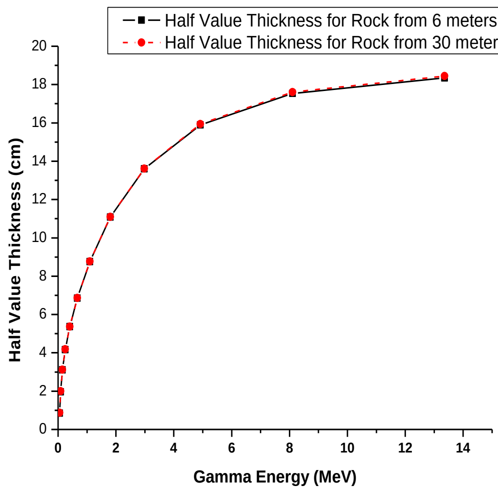

Figure 6 Half-Value Thickness for both rock samples.

$$I=I_o\, e^{-\mu x} \qquad (2)$$

For tenth-value thickness:

$$1/10 = e^{-\mu x}$$

$$10 = e^{\mu x}$$

$$\text{Ln } 10 = \mu x$$

$$X = \ln 10 / \mu$$

Where : I_o is the gamma beam intensity incident on the shield, I is the intensity of the emergent gamma beam from the shield (or attenuated beam), μ (cm^{-1}) is the linear attenuation coefficient of the shield material, and x (cm) the mean path length of a gamma-ray in the shield.

Conclusions

It is found that no significant differences in gamma attenuation properties of the rocks from 6 and 30 meters depths from North West coast of Egypt. The gamma attenuation properties were found independent on the type of rock, provided that the rock density is almost equal. However, gamma attenuation coefficient showed inverse exponential dependence on the gamma energy. Further investigations are highly needed in order to cover the attenuation characteristics of a wide ranges of host rocks to include volcanic,plutonic and sedimentary rocks.

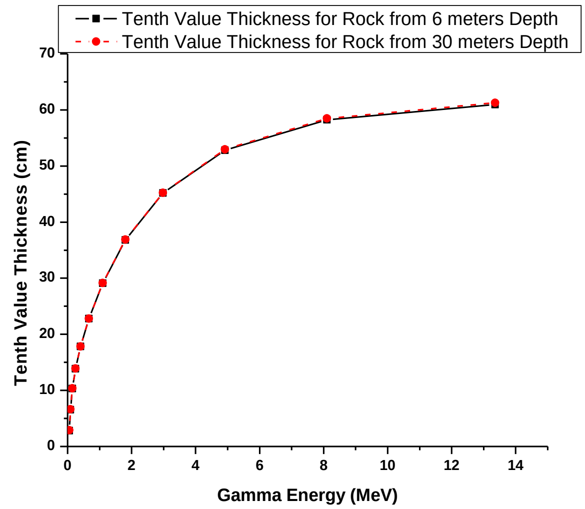

Figure 7 Tenth-Value Thickness for both rock samples.

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