Global Journal of
Technology & Optimization

Al-Gamal, et al., Global J Technol Optim 2016, 7:2
DOI: 10.4172/2229-8711.1000198

Research Article Open Access

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

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Rec date: Jul 13, 2016; **Acc date:** Jul 18, 2016; **Pub date:** Jul 22, 2016

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 Code for Nuclear Power (MCNP). Carbonates rock samples were taken to represents 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 roch sample density remains constant. Ultimately it is found that, gamma attenuation coefficient showed an inverse exponential dependence on the gamma energy regardless rock type and their related depth.

Keywords: Gamma; Nuclear power; Carbonate rocks

Introduction

The main objective of this study was to significantly improve the knowledge of the local rock attenuation characteristics using Monte-Carlo Code for Nuclear Power (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.

Study area and dealt with 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. The west coast of Egypt is mainly composed of pure oolitic carbonate [1-3]. The oolitic grains constitute an average of 78% and 89% of the bottom and beach sediments, respectively.

Monte- Carlo Code for Nuclear Power (MCNP)

Gamma-ray attenuation is known to depend mainly on density of material rather than is composition. Physical examination of the rocks taken from 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 [4].

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

Where:

Io 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 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.

Methodologies and Techniques

Rocks samples from Al-Dabaa locality (North Western Coast of Egypt) at a depth from ground surface, 6 m and 30 m were used to shield Gamma photons emitted by a virtual mono-energetic isotropic point source. The geometry was a 5.0 cm thick spherical shield of the rock material, with the gamma source at its center, as shown in Figure 1.

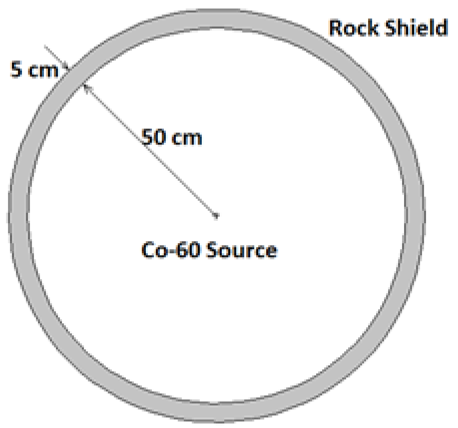

Figure 1: Geometry of the MCNP model.

Rock samples corresponding to the foregoing depths; 6 and 30 m respectively were also analyzed for chemical compositions and expressed in terms of oxides (Table 1) as well as major elements (Table 2).

Physical densities of the rocks were: 2.0 and 2.1 g/cm^3 for the 6 and 30 meters depth rocks respectively (Figure 2).

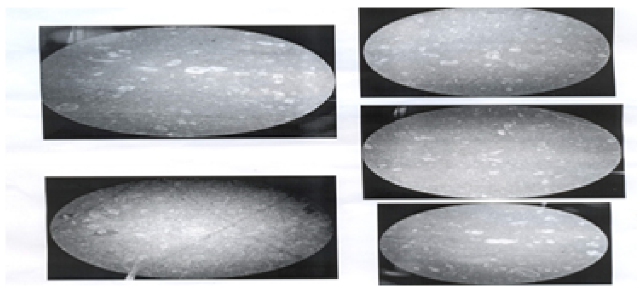

Figure 2: Microscopic structure of the host carbonate rock.

Results and Discussion

Calculations showed that the dose attenuation coefficient of the rock material for a 5 cm thick shield was as in Figure 3.

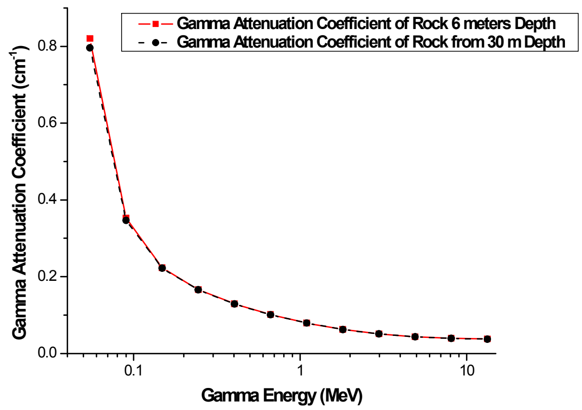

Figure 3: The calculated gamma attenuation coefficient.

Depth	CaO	CO_2	Al_2O_3	SiO_2	MgO	K_2O	Na_2O
6 m	56.00	43.44	0.5%	0.5%	0.056%	0.056%	0.056%
30 m	51.68%	40.61%	3%	3%	0.57%	0.57%	0.57%

Table 1: Chemical composition of the rock.

Element w/o	C	O	Na	Mg	Al	Si	K	Ca	Fe
6 m	11.856	48.1407	0.0415	0.0338	0.2646	0.2337	0.0465	40.0226	0.081
30 m	11.083	47.7519	0.4229	0.3437	1.5878	1.4023	0.4732	36.9352	--

Table 2: Element composition of the rock.

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 4 illustrates "Half-value thickness" for both rock samples. "Half-value thickness" of a material is the thickness required for reducing the intensity of radiation by one half.

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

For half-value thickness:

$$½ = e^{-\mu x}$$

$$2 = e^{\mu x}$$

$$Ln\, 2 = \mu X$$

$$X = \ln 2 / \mu$$

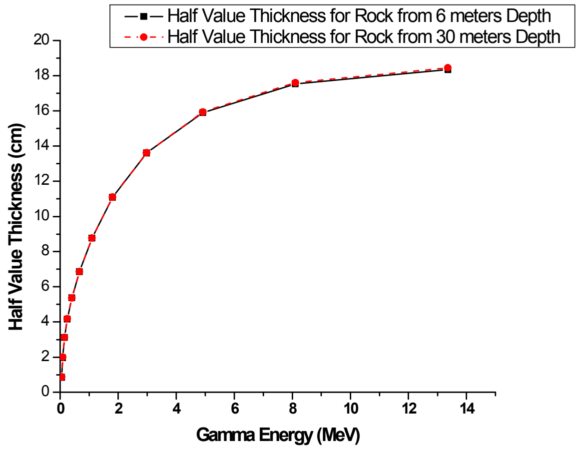

Figure 4: "Half-value thickness" for both rock samples.

Figure 5 illustrates "Tenth-value thickness" for both rock samples. "Tenth-value thickness" of a material is the thickness required for reducing the intensity of radiation by a factor of 10.

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

For tenth-value thickness:

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

$10 = e^{\mu x}$

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

$X = \ln 10 / \mu$

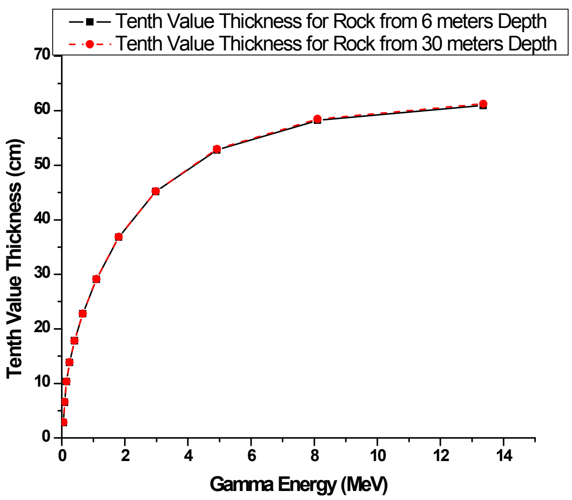

Figure 5: "Tenth-value thickness" for both rock samples.

Conclusion

There were 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, given the density is almost equal. However, gamma attenuation coefficient showed inverse exponential dependence on the gamma energy.

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