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Investigation of Gamma Rays Shielding Parameters of some Building Materials used in Sudan

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Abstract: In this study the gamma ray shielding properties of some building materials used in Sudan has been investigated, the photon attenuation coefficients and the half value layer (HVL), have been experimentally determined using Cs-137 and Co-60 source. The measurements were performed for radiation intensity without shielding and with specific thickness of selected samples (building materials), using ion chamber placed at 2 meters from Cs-137 and Co-60. An obtained results showed that the linear attenuation coefficient (μ) has a linear relationship with the corresponding densities of the samples studied and inversely with photon energy, and the half value layer (HVL) was proportional directly with photon energy. As a results of this evaluation the selected samples could be used as a shielding for gamma radiation.

Keywords: Gamma radiation, attenuation coefficient, half value layer, shielding, building materials.

1. Introduction

Due to the use of radiation in many fields such as industrial, medical and agricultural, etc. So the gamma radiation penetration through matter depends on the photon energy and the nature of absorbing material (F. Bouzarjomehri, 2006). So that it is necessary to study different parameters related to the passage of gamma radiation through a building materials, and experimentally obtained the gamma ray shielding parameters such as half value layer, linear and mass attenuation coefficients to know the effectiveness of building materials as the gamma ray shielding. Different workers have been calculated the attenuation coefficients in different categories such as (Tugrul, 2014) in Lead and WC_Co Materials against Gamma Irradiation, (Reda, 2016) used Aluminum, Iron, Copper and Lead, (Ayodeji, 2016) in building block, concrete, iron and lead, (Samarin, 2013) design and construction of light and heavy weight concrete biological shields from ionizing radiation, (S.M.R. Aghamiri, 2014) in heavy concrete, (Anon., 2006) in Cement material, (Suat AKBULUT, 2015) in clay, silica fume and cement samples, (Harjinder Singh, 2015) used clay-flyash bricks, (Canakci, 2011) in boron doped clay for 662, 1173 and 1332 keV gamma rays (Charanjeet Singh, 2004) in glass, concrete, marble, fly ash, cement and lime.

2. Materials and Methods

Selected building materials (Clay, Cement mortar, Concrete Mix Design) as samples for shielding and prepared separately: The concrete mix was designed according to the British design method and the design result was as follows:

The mixture was designed to give strength of 25 n / mm^2 and the concrete was then mixed and casted into (150 * 150 * 150 mm and 100 * 100 * 100 mm) cubes. For Cement mortar which mixed by 1 cement was mixed with 4 sand and 0.5 water and Cubes were casting in the same way for the concrete mix. For clay Proctor test was performed of clay sample to determine the optimum moisture content of the clay. The result was a 40% optimum moisture content, of clay weight. The feature of lead and iron materials used was in form of slabs with different thicknesses, the density of lead, iron, concrete, cement and clay was 11.34 (g/cm^3**)**, 7.87 (g/cm^3), 2.374 (g/cm^3), 2.139(g/cm^3) and 1.335 (g/cm^3) respectively.

Experimental setup:

The measurement was performed at secondary standard dosimetry laboratory (SSDL –Sudan) in order to determine the air kerma rate as radiation intensity at a reference distance from γ source (Co-60, Cs-137) located inOB-85 Irradiator two lead attenuators are available that are placed at the exit window of the irradiator so shielding samples was placed at this point, and connected to Electrometer UNIDOS, Thermometer and barometer were used to conduct this measurement. Concerning dosimetry systems, the laboratory has one secondary standard ionization chamber designed and manufactured at the Austrian research centre, Siebersdorf. This chamber was calibrated at IAEA laboratory with its calibration traceable to the German National Laboratory (PTB). Ionization chamber was placed at 2 meters from Cs-137 source as usual in reference standard measurements. Measurements of linear attenuation coefficients; γ-ray beam used here was characterized in terms of air kerma as radiation intensity without attenuator after that adding attenuator with constant operation voltage 400 volt , to calculate linear attenuation coefficient (Agency, 2000).

Linear attenuation coefficient

The attenuation coefficient measures the probability of all possible interactions between gamma rays and atomic nuclei, it is important for solving various problems in radiation physics and in radiation dosimetry. The probability of a photon interacting in a particular way with a given material, per unit path length is usually called the linear attenuation coefficient μ, is great importance in radiation shielding. Linear attenuation coefficients depend on the density $\boldsymbol{\rho}$ of the shielding material, the incident photon energy and the nature of the absorbing material.

$$\mu = \frac{1}{x}\ln\left(\frac{I_0}{I}\right) \qquad (1)$$

Where μ is the linear attenuation coefficient in(cm^{-1}) and $\boldsymbol{x}$ is the thickness of the sample in (cm). (M.N. Alam, 2001) (Abdo, 2002) (I.C.P. Salinas, 2006).

Mass attenuation coefficient

Mass attenuation coefficientμ_m is an important parameter for study of interaction of radiation with matter that gives us the fraction of energy scattered or absorbed, it is a measure of probability of interaction that occurs between incident photons and matter in a given mass per unit area thickness of the material encountered. It is a basic quantity used in the calculation of photon penetration and energy deposition in biological, shielding and other dosimetric materials. The magnitude of $\mu_m$depends on the incident photon energy, the chemical structure and bonding in the absorbing material and parameters such as thickness and density $\boldsymbol{\rho}$.

$$\mu_m = \mu/\rho \qquad cm^2 g^{-1} \qquad (2)$$

(Y. Elmahroug, 2015) (Charanjeet Singh, 2004)

Half Value Layer

The thickness of any given material where 50% of the incident energy has been attenuated is known as the half value layer HVL, useful parameters for understanding the interaction of gamma ray and depends on linear attenuation coefficient, is expressed in units of distance (cm). A half value of layer of shielding material, $X_{1/2}$ defined at $I = \frac{I_0}{2}$, is given as:

$$X_{1/2} = \frac{0.693}{\mu} \tag{3}$$

(El-Sayed A. Waly, 2016) (Ravinder Singh, 2017) (I. Akkurt, 2012).

3. Results and Discussion

Table1. The value of Doses through different lead and iron slabs thickness by using Cs-137 source. The measuring time, temperature and pressure were 60s, 24.6 c^0 and 968.9hpa, respectively.

Lead thickness(cm)	Dose(µGY)	Iron thickness(cm)	Dose(µGY)	Frequency
0.000	474.76	0.000	474.74	10
0.154	400.46	0.202	434.58	10
0.472	274.69	0.522	373.03	10
0.812	190.42	1.036	289.54	10
0.966	164.63	1.350	249.21	10

Table2. The value of Doses through different lead and iron slabs thickness by using Co-60 source. The measuring time, temperature and pressure were 30s, 24.6 c^0 and 968.9hpa, respectively.

Lead thickness(cm)	Dose(µGY)	Iron thickness(cm)	Dose(µGY)	Frequency
0.000	1.906	0.000	1.906	10
0.154	1.744	0.202	1.797	10
0.472	1.428	0.522	1.602	10
0.812	1.169	1.036	1.346	10
0.966	1.079	1.350	1.202	10

Table3. The value of Doses through different building materials cubic's thickness by using Cs-137 source. The measuring time, temperature and pressure were 30s, 30 c^0 and 964.7hpa, respectively.

Thickness(cm)	Dose(µGY) through concrete shield	Dose(µGY) through cement shield	Dose(µGY) through clay shield	Frequency
0	225.65	225.65	225.65	10
10	43.37	49.99	77.05	10
20	9.45	12.10	27.26	10
25	4.93	7.04	18.24	10
35	2.27	2.81	7.86	10

Table4. The value of Doses through different building materials cubic's thickness by using Co-60 source. The measuring time, temperature and pressure were 30s, 34.5c^{0} and 964.8hpa, respectively.

Thickness(cm)	Dose(μGY) through concrete shield	Dose(μGY) through cement shield	Dose(μGY) through clay shield	Frequency
0	1.906	1.906	1.906	10
10	0.561	0.636	0.856	10
20	0.178	0.218	0.396	10
25	0.109	0.141	0.301	10
35	0.053	0.072	0.177	10

Table5. Attenuation coefficient and half value layer for selected shielding materials using Cs-137 gamma rays.

Materials	**Linear attenuation coefficient μ(cm^{-1})**	**Standard error (cm^{-1})**	**Mass attenuation coefficient μ_m (cm^2/g)**	**Standard error (cm^2/g)**	**Half value layer(cm)**	**Standard error (cm)**
Lead	1.121	0.028	0.098	0.001	0.617	0.008
Iron	0.463	0.009	0.058	0.001	1.496	0.031
Concrete	0.151	0.007	0.063	0.003	4.593	0.236
Cement	0.139	0.006	0.065	0.003	4.965	0.206
Clay	0.101	0.003	0.076	0.002	6.779	0.175

Table6. Attenuation coefficient and half value layer for selected shielding materials using Co-60 gamma rays

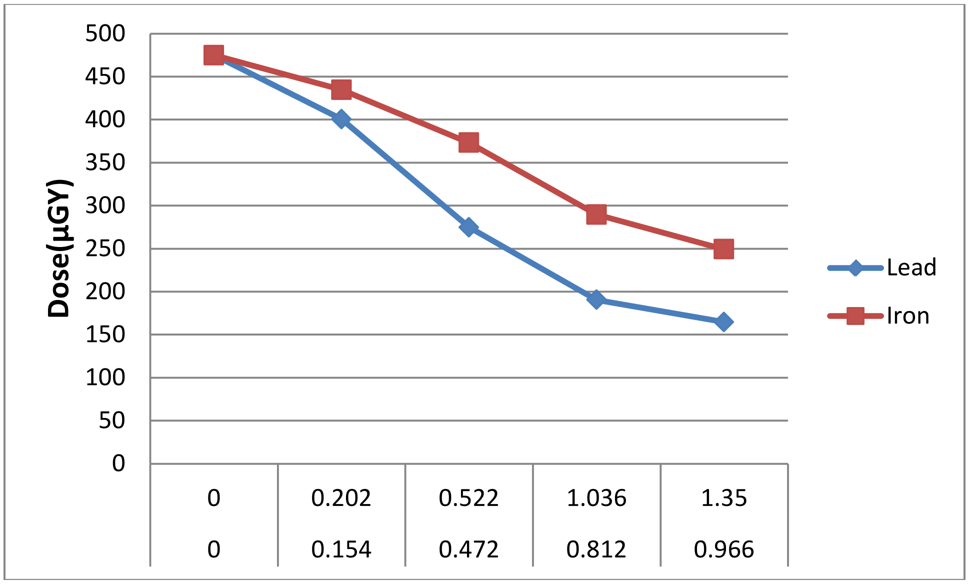
Materials	**Linear attenuation coefficient μ(cm^{-1})**	**Standard error (cm^{-1})**	**Mass attenuation coefficient μ_m (cm^2/g)**	**Standard error (cm^2/g)**	**Half value layer(cm)**	**Standard error (cm)**
Lead	0.594	0.015	0.051	0.001	1.167	0.034
Iron	0.325	0.023	0.041	0.002	2.137	0.161
Concrete	0.114	0.009	0.046	0.004	6.084	0.484
Cement	0.104	0.007	0.048	0.004	6.691	0.497
Clay	0.075	0.006	0.056	0.005	9.267	0.699

In this study the decrease of 662, 1173 and 1332 keV gamma rays with the increase the thickness of selected materials have been obtained, for each energy the measurements for all types of samples were carried out ten times and the average values listed in Tables 3, 4, 5 and 6. Also the attenuation coefficients and half value layer for the all studied building materials have been obtained for 662, 1173 and 1332 keV gamma rays and the results have been listed in Tables 7 and 8.

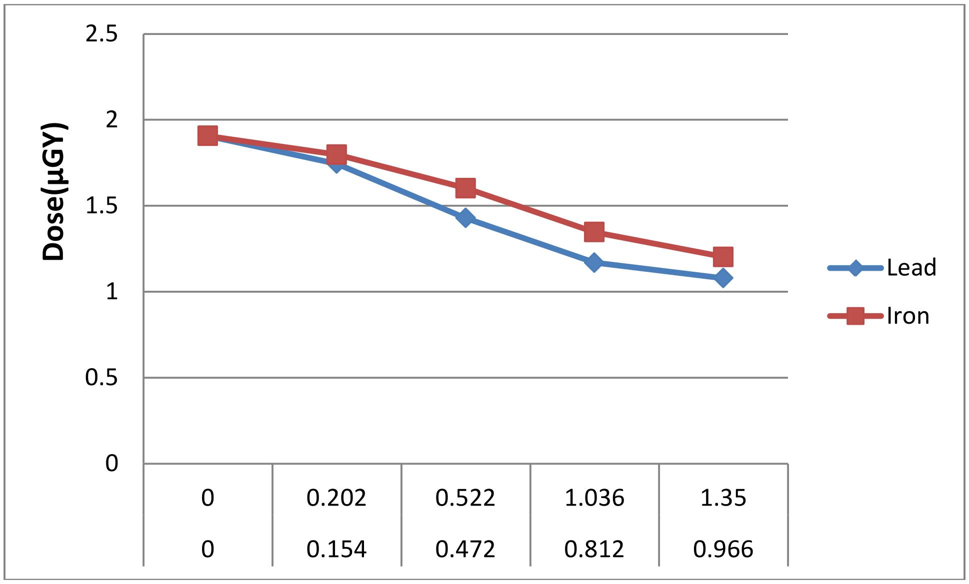
Figures 1, 2, 3 and 4 show graphical patterns that describe how the photon was attenuated in the materials studied with increased the thickness, through different energies of gamma ray.

Figure5 shows the comparison of half value layers values (HVL) for the selected materials through two gamma ray energies, Cs-137 and Co-60. The results showed an directly relationship between the HVL values and the energies.

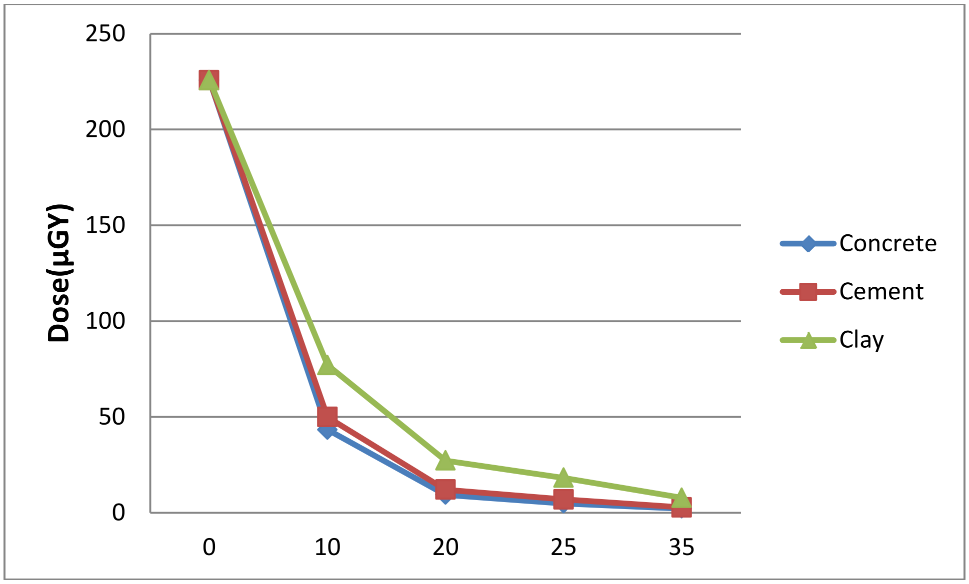
In Figure6, shows the comparison of linear attenuation coefficients (μ) values for the selected materials through two gamma ray sources, Cs-137 and Co-60, and the variation of linear attenuation coefficients with energy is shown also. It is observed that the linear attenuation coefficient of each one decreases with increase energy region (inverse relationship), this can be explained due to density-dependence of these materials.



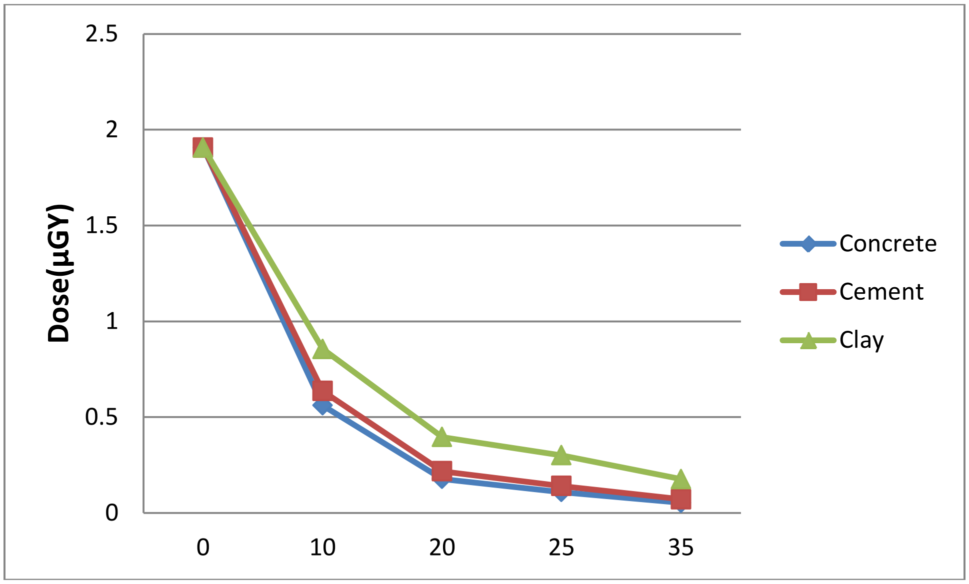
Fiqure1. Attenuation of Cs-137 gamma rays as a function of thickness through different shield materials.



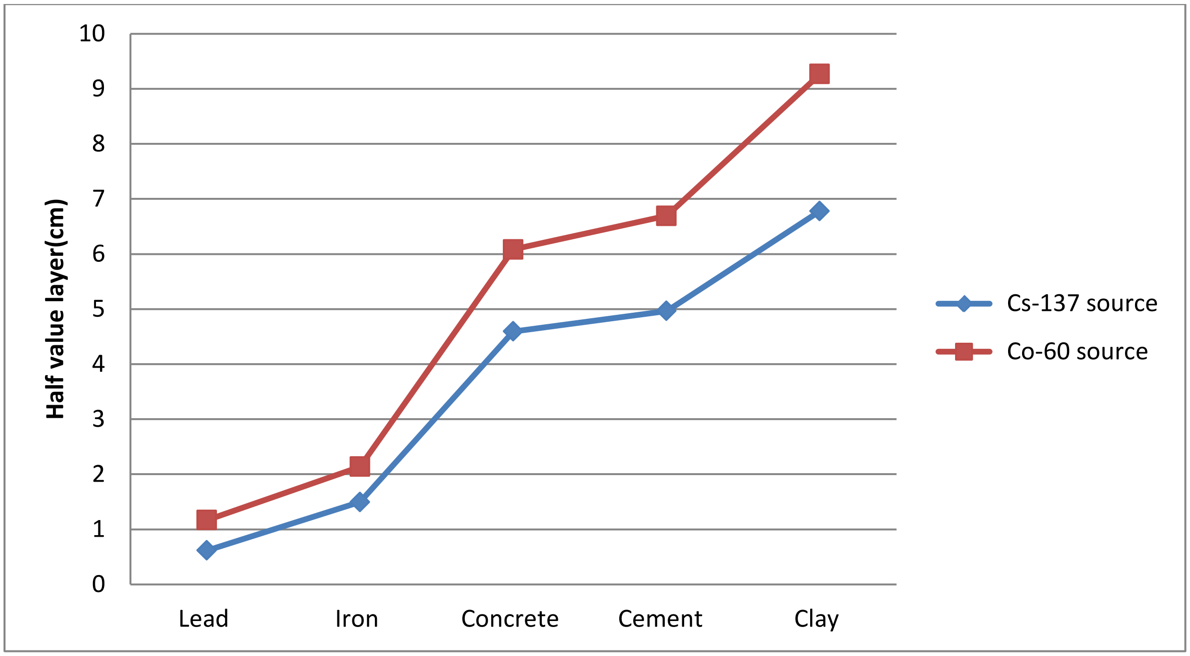
Fiqure2. Attenuation of Co-60 gamma rays as a function of thickness through different shield materials.



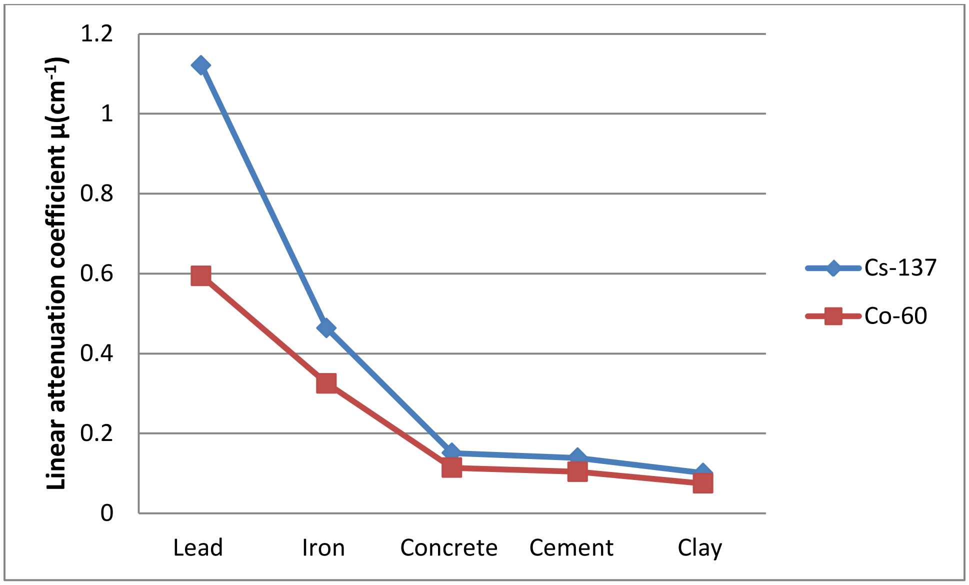
Fiqure3. Attenuation of Cs-137 gamma rays as a function of thickness through different shield materials.



Fiqure4. Attenuation of Co-60 gamma rays as a function of thickness through different shield materials.



Fiqure5. Comparison of half value layer of different materials shield using different gamma ray sources.



Fiqure6. Comparison of linear attenuation coefficient of the materials shield as a function of photon energy.

4. Conclusion

Gamma ray shielding properties of some building materials have been evaluated and discussed in terms of attenuation coefficients and half value layer at different gamma ray energies. The investigated materials are commonly used as a building materials in Sudan showed the linear attenuation coefficients decrease with the increasing photon energy, and half value layer increase with increasing photon energy for these materials. From the present study, it was found that among the investigated building materials can use as a gamma ray shielding materials.

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