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Abstract

In this work, fast neutron and gamma ray shield attenuation parameters have been calculated for new composite paste shielding with seven different concentrations of high-density polyethylene (HDPE) and borax (BX) that are mixed with cement and sand. Computer program WinXCom has been used to calculate the total mass attenuation coefficients (μ/ρ) for gamma rays at energies from 0.01 MeV to 100 MeV. In addition, the fast neutron removal cross-sections (Σ_R) are calculated using the cross-section database for used elements in the composites. The obtained results are used to calculate half value layer (HVL) and relaxation length (λ) as well. The calculated results were compared with experimental results and with all available concrete shields in literature. A reasonable agreements are found which indicated that the composite of 12.5% HDPY, 37.5% BX, has the most significant effect on dose rate reduction and has higher radiation attenuation parameters for neutron and gamma rays. In addition, this composite has the lowest thickness over all available shields, which 10 cm from this composite can attenuate 89 % of neutrons and gamma rays.

Keywords: Mass attenuation coefficients; Effective removal cross-sections; High density polyethylene; Borax; Composite paste.

1. Introduction

The shield design for neutrons and gamma rays are of the most important one that to be considered in radiation safety, which, any shield attenuates them can attenuate other radiations. In the last few years, several studies have been devoted to develop the shielding materials by changing the properties of different materials [1-5]. The neutrons and gamma rays interaction with matters is reasonably well understood where their relative importance depends on largely unknown physical parameters called cross sections [6]. Linear attenuation coefficient (μ cm^{-1}) is the important quantity that characterizing the diffusion and penetration of gamma rays through shielding. Since (μ) depends on the density (ρ) and the physical state of the shielding or its content, so it must express as a mass attenuation coefficient (μ/ρ cm^2 g^{-1}) to obviate the effects of variations in the material density [7]. Several theoretical and experimental studies are performed to obtain (μ) and (μ/ρ) for elements, mixtures and for different types of concrete. [8-17].

For the construction of neutron shielding system, hydrogenous material mixed with boron material should be used to moderate fast neutrons through elastic scattering process and that is necessary for enhancing neutrons reaction $^{10}B_5$ (n, α) $^{7}Li_3$ yielding 1.47 MeV α particles average [18-19]. For this reason, materials containing boron are used often in neutron shields. The effect of the materials is described by the effective removal cross-section Σ_R (cm^{-1}) which means removal from the fast group or it is the probability that a fast neutron undergo to the first collision that remove it from the penetrating group, uncollided neutrons [20]. If the shielding contains moderating material, so this removal process will determine the attenuation of neutrons.

Recently, many computer programs were developed to calculate Σ_R and μ/ρ for fast neutrons and gamma rays respectively for any homogeneous mixture or composite. the XCom programs are used to calculate μ/ρ, $cm^2\ g^{-1}$. In addition, the MERCSF-N program was used to calculate Σ_R/ρ, $cm^2\ g^{-1}$ and removal cross-sections Σ_R, cm^{-1} [21-25]. Therefore, studying the effect of different materials of concrete on radiation shielding properties will be useful in the development of the shielding design.

It was reported that the replacement of polyethylene and borax in concrete greatly enhanced the shielding efficiency of the concrete as it reduces of gamma rays up to 80% better than unborated concretes [26-30]. Therefore, in the present study, attenuation parameters of gamma rays and fast neutron were calculated theoretically for new composites paste containing seven different concentrations of high-density polyethylene (HDPE) and borax (BX) with cement and sand. The calculated results will be compared with our previous experimental results [31].

2. Methodology

2.1. Gamma rays attenuation parameter

The interaction of photons (with intensity I_0) with the medium can be described by three main processes is reasonably well understood. The total probability of the interaction called linear attenuation coefficient μ (cm^{-1}), which can be given by:

$$I = I_0\, e^{-\mu x} \qquad (1)$$

Where I is the attenuated photon intensities and x is the shielding thickness. The μ/ρ ($cm^2\ g^{-1}$) is obtained by using the density of the shielding (ρ):

$$\mu/\rho = (1/\rho x)\ \ln (I_0/I) \qquad (2)$$

So, the interaction coefficients and total mass attenuation coefficients for any mixture of shielding materials, the $(\mu/\rho)_{compound}$ can be given by [7]:

$$(\mu/\rho)_{\text{compound}} = \sum_i w_i (\mu/\rho)_i \qquad (3)$$

Where ρ is the mass density of the sample and w_i is the weight fraction i^{th} component. In the compound, the weight fraction of ith element is given by:

$$w_i = \frac{a_i\, M_i}{\sum a_i\, M_i} \qquad (4)$$

Where, a_i and M_i are the number of formula units and atomic weight of the i^{th} element. The half-value thickness HVT (cm) and the relaxation length of the photon λ can be calculated as following [32]: $HVL = \frac{Ln\ 2}{(\mu/\rho)\rho}$ and $\lambda = \frac{1}{(\mu/\rho)\rho}$

In the present work, the calculations were performed for composites (C_1, C_2, C_3, C_4, C_5, C_6 and C_7) containing seven concentration of high density Polyethylene (HDPE) and commercial borax (BX) [$Na_2B_4O_710H_2O$], as given in Table 1, which mixed with 25 % (wt) sand and 25 % (wt) Portland cement (PC). The WinXCom program at energies from 0.01 MeV to 100 MeV and database cross-section for elements has been used to calculate the μ/ρ for the demonstrated composites. The fractions by weight for the elements of composites were calculated using eq. (4) and listed in Table 2.

Table 1. The concentration of HDPE and BX in seven shielding composite.

Samples	**Material (Wt. %)**		**Density ρ(gcm^{-3})**
	HDPE	**BX**	
C_1	43.75	6.25	1.78
C_2	37.5	12.5	1.82
C_3	31.25	18.75	1.85
C_4	25	25	1.90
C_5	18.75	31.25	1.98
C_6	12.5	37.5	2.06
C_7	6.25	43.75	2.08

Table 2. Elemental compositions as fraction by weight (%) of the seven paste composites.

Element (w%)	**Composite number**						
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**
H	6.85E-02	6.72E-02	6. 56E-02	5.86E-02	5.88E-02	6.08E-02	5.99E-02
B	1.24E-02	2.03E-02	3.98E-02	5.99E-02	6.74E-02	7.58E-02	7.72E-02
C	4.97E-01	4.26E-01	3.52E-01	2.84E-01	2.03E-01	1.42E-01	7.11E-02
O	1.48E-01	2.32E-01	3.05E-01	3.71E-01	4.65E-01	5.30E-01	5.44E-01
Na	3.03E-02	4.04E-02	5.55E-02	6.95E-02	7.55E-02	9.53E-02	1.59E-01
Mg	9.14E-03	9.14E-03	9.13E-03	9.13E-03	9.14E-03	9.14E-03	9.13E-03
Al	1.74E-02	1.73E-02	1.72E-02	1.73E-02	1.73E-02	1.74E-02	1.73E-02
Si	1.06E-02	1.06E-02	1.05E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02
S	2.34E-02	2.34E-02	2.33E-02	2.34E-02	2.34E-02	2.34E-02	2.34E-02
Ca	1.21E-02	1.21E-02	1.20E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02
Fe	2.95E-02	2.95E-02	2.93E-02	2.95E-02	2.95E-02	2.95E-02	2.95E-02
K	1.51E-02	1.51E-02	1.50E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02
P	2.81E-02	2.81E-02	2.79E-02	2.81E-02	2.81E-02	2.81E-02	2.81E-02
Ti	4.24E-02	4.24E-02	4.21E-02	4.24E-02	4.24E-02	4.24E-02	4.24E-02

Table 3. Total mass attenuation coefficients μ/ρ for seven samples composite paste.

Photon energy (MeV)	Total mass attenuation coefficients(μ/ρ) for samples						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
1.00E-02	2.07E+01	1.60E+01	1.75E+01	1.99E+01	2.11E+01	3.08E+01	2.03E+01
1.50E-02	6.65E+00	5.18E+00	5.67E+00	6.44E+00	6.76E+00	9.62E+00	6.55E+00
2.00E-02	3.00E+00	2.36E+00	2.58E+00	2.91E+00	3.04E+00	4.23E+00	2.96E+00
3.00E-02	1.04E+00	8.47E-01	9.14E-01	1.02E+00	1.05E+00	1.39E+00	1.03E+00
4.00E-02	5.44E-01	4.65E-01	4.93E-01	5.37E-01	5.48E-01	6.88E-01	5.41E-01
5.00E-02	3.62E-01	3.24E-01	3.38E-01	3.60E-01	3.63E-01	4.35E-01	3.61E-01
6.00E-02	2.79E-01	2.58E-01	2.67E-01	2.79E-01	2.79E-01	3.21E-01	2.79E-01
8.00E-02	2.07E-01	2.01E-01	2.04E-01	2.09E-01	2.06E-01	2.26E-01	2.08E-01
1.00E-01	1.77E-01	1.76E-01	1.77E-01	1.79E-01	1.76E-01	1.87E-01	1.78E-01
1.50E-01	1.45E-01	1.47E-01	1.47E-01	1.47E-01	1.44E-01	1.49E-01	1.46E-01
2.00E-01	1.29E-01	1.32E-01	1.32E-01	1.31E-01	1.28E-01	1.31E-01	1.30E-01
3.00E-01	1.10E-01	1.13E-01	1.13E-01	1.12E-01	1.09E-01	1.11E-01	1.11E-01
4.00E-01	9.83E-02	1.01E-01	1.01E-01	1.00E-01	9.73E-02	9.91E-02	9.93E-02
5.00E-01	8.96E-02	9.20E-02	9.18E-02	9.14E-02	8.87E-02	9.02E-02	9.05E-02
6.00E-01	8.28E-02	8.50E-02	8.48E-02	8.44E-02	8.19E-02	8.33E-02	8.36E-02
6.62E-01	7.92E-02	8.14E-02	8.12E-02	8.08E-02	7.84E-02	7.97E-02	8.00E-02
8.00E-01	7.26E-02	7.46E-02	7.44E-02	7.41E-02	7.19E-02	7.31E-02	7.33E-02
1.00E+00	6.53E-02	6.71E-02	6.69E-02	6.66E-02	6.46E-02	6.57E-02	6.59E-02
1.02E+00	6.46E-02	6.64E-02	6.62E-02	6.59E-02	6.39E-02	6.50E-02	6.52E-02
1.13E+00	6.14E-02	6.31E-02	6.30E-02	6.27E-02	6.08E-02	6.28E-02	6.20E-02
1.17E+00	5.83E-02	6.00E-02	5.98E-02	5.95E-02	5.78E-02	6.13E-02	5.89E-02
1.25E+00	5.65E-02	5.81E-02	5.79E-02	5.77E-02	5.59E-02	5.96E-02	5.71E-02
1.33E+00	4.57E-02	4.69E-02	4.68E-02	4.66E-02	4.53E-02	4.69E-02	4.62E-02
1.50E+00	4.52E-02	4.64E-02	4.63E-02	4.61E-02	4.47E-02	4.56E-02	4.56E-02
2.00E+00	3.70E-02	3.79E-02	3.78E-02	3.77E-02	3.67E-02	3.76E-02	3.73E-02
2.04E+00	3.20E-02	3.26E-02	3.26E-02	3.25E-02	3.18E-02	3.28E-02	3.23E-02
3.00E+00	2.88E-02	2.92E-02	2.92E-02	2.92E-02	2.86E-02	2.97E-02	2.90E-02
4.00E+00	2.66E-02	2.68E-02	2.69E-02	2.69E-02	2.64E-02	2.77E-02	2.67E-02
5.00E+00	2.50E-02	2.51E-02	2.51E-02	2.52E-02	2.49E-02	2.62E-02	2.51E-02
6.00E+00	2.38E-02	2.38E-02	2.38E-02	2.39E-02	2.37E-02	2.51E-02	2.38E-02
7.00E+00	2.28E-02	2.27E-02	2.28E-02	2.30E-02	2.28E-02	2.43E-02	2.29E-02
8.00E+00	2.21E-02	2.19E-02	2.20E-02	2.22E-02	2.20E-02	2.37E-02	2.21E-02
9.00E+00	2.15E-02	2.13E-02	2.14E-02	2.15E-02	2.15E-02	2.32E-02	2.15E-02
1.00E+01	2.10E-02	2.07E-02	2.08E-02	2.10E-02	2.10E-02	2.28E-02	2.10E-02
1.10E+01	2.06E-02	2.02E-02	2.04E-02	2.06E-02	2.06E-02	2.25E-02	2.06E-02
1.20E+01	2.03E-02	1.99E-02	2.00E-02	2.02E-02	2.03E-02	2.22E-02	2.03E-02
1.30E+01	2.00E-02	1.95E-02	1.97E-02	1.99E-02	2.00E-02	2.20E-02	2.00E-02
1.40E+01	1.98E-02	1.93E-02	1.94E-02	1.97E-02	1.98E-02	2.19E-02	1.97E-02
1.50E+01	1.94E-02	1.88E-02	1.90E-02	1.93E-02	1.95E-02	2.16E-02	1.94E-02
1.60E+01	1.92E-02	1.85E-02	1.87E-02	1.90E-02	1.92E-02	2.15E-02	1.91E-02
1.80E+01	1.90E-02	1.83E-02	1.85E-02	1.88E-02	1.91E-02	2.14E-02	1.89E-02
2.00E+01	1.89E-02	1.81E-02	1.83E-02	1.87E-02	1.90E-02	2.14E-02	1.88E-02

Table 3. (Continued)

Photon energy (MeV)	Total mass attenuation coefficients(μ/ρ)for samples						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7
2.20E+01	1.88E-02	1.80E-02	1.82E-02	1.85E-02	1.89E-02	2.14E-02	1.87E-02
2.40E+01	1.87E-02	1.79E-02	1.81E-02	1.85E-02	1.89E-02	2.14E-02	1.86E-02
2.60E+01	1.87E-02	1.78E-02	1.80E-02	1.84E-02	1.88E-02	2.15E-02	1.86E-02
2.80E+01	1.87E-02	1.77E-02	1.79E-02	1.84E-02	1.89E-02	2.18E-02	1.86E-02
3.00E+01	1.89E-02	1.78E-02	1.80E-02	1.85E-02	1.91E-02	2.22E-02	1.87E-02
4.00E+01	1.92E-02	1.79E-02	1.82E-02	1.87E-02	1.94E-02	2.26E-02	1.90E-02
5.00E+01	2.07E+01	1.60E+01	1.75E+01	1.99E+01	2.11E+01	3.08E+01	2.03E+01
6.00E+01	6.65E+00	5.18E+00	5.67E+00	6.44E+00	6.76E+00	9.62E+00	6.55E+00
8.00E+01	1.97E-02	1.83E-02	1.86E-02	1.92E-02	1.99E-02	2.34E-02	1.94E-02
1.00E+02	2.01E-02	1.86E-02	1.90E-02	1.95E-02	2.04E-02	2.40E-02	1.98E-02
1.50E+02	2.09E-02	1.93E-02	1.97E-02	2.03E-02	2.12E-02	2.51E-02	2.06E-02
2.00E+02	2.15E-02	1.98E-02	2.02E-02	2.09E-02	2.18E-02	2.59E-02	2.12E-02
3.00E+02	2.23E-02	2.05E-02	2.09E-02	2.16E-02	2.26E-02	2.68E-02	2.20E-02
4.00E+02	2.28E-02	2.10E-02	2.14E-02	2.21E-02	2.31E-02	2.74E-02	2.24E-02
5.00E+02	2.31E-02	2.13E-02	2.17E-02	2.24E-02	2.34E-02	2.78E-02	2.27E-02
6.00E+02	2.33E-02	2.15E-02	2.19E-02	2.26E-02	2.37E-02	2.81E-02	2.30E-02
8.00E+02	2.37E-02	2.18E-02	2.22E-02	2.30E-02	2.40E-02	2.85E-02	2.33E-02
1.00E+03	2.39E-02	2.20E-02	2.24E-02	2.32E-02	2.43E-02	2.88E-02	2.35E-02

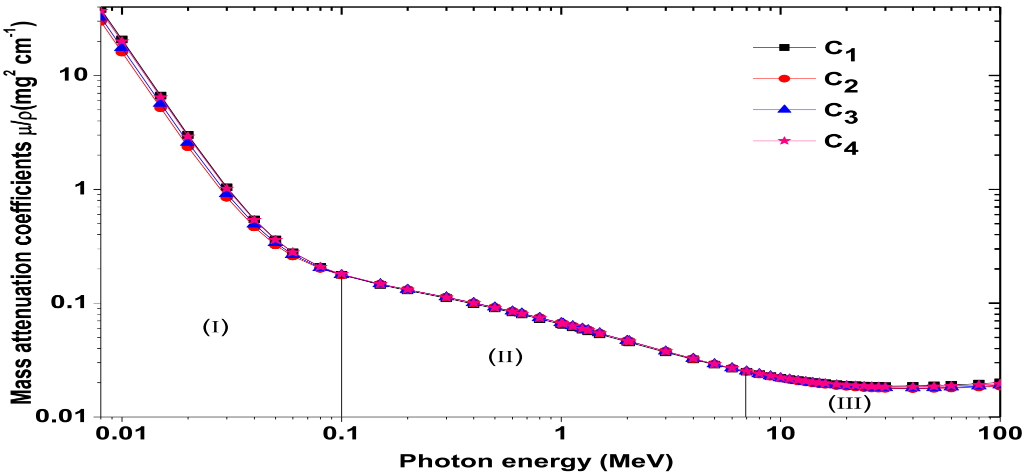

Figure 1. Total mass attenuation coefficients for composites C_1, C_2, C_3 and C_4

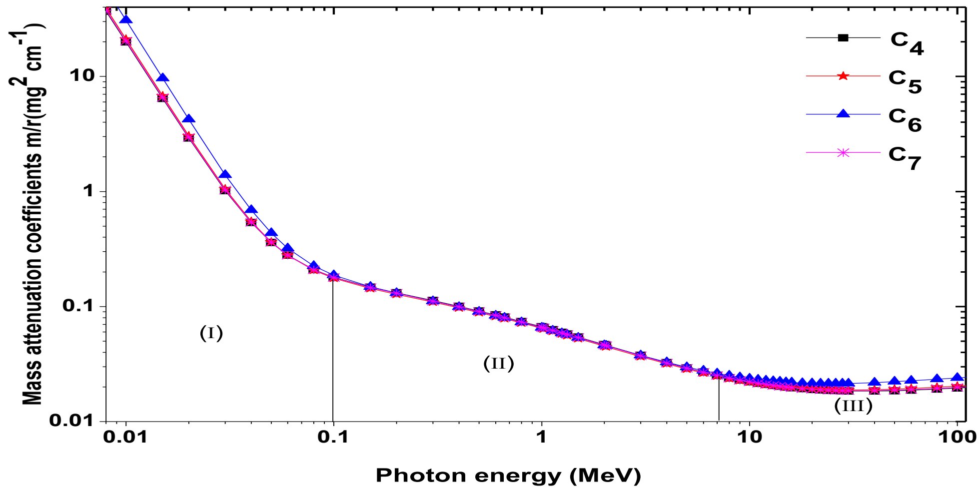

Figure 2. Total mass attenuation coefficients for composites paste C_4, C_5, C_6 and C_7.

2.2. The effective removal cross-section (Σ_R)

An approximate method for calculating the attenuation of fast neutron can be achieved by using the macroscopic effective removal cross-section. The effective removal cross-section for compounds and homogeneous mixtures may be calculated from the value Σ_R (cm^{-1}) or Σ_R/ρ (cm^2 g^{-1}) for various elements in the compounds or mixtures as in Eqs. (3), but in which Σ_R replaces μ [7, 33], w_i is the partial density (g.cm^{-3}) and ρ refers to ith composite density. Then the effective removal cross-section (Σ_R) of fast neutrons can be evaluated for the composites of interest using:

$$\Sigma_R / \rho = \sum_i w_i (\Sigma_R/\rho)_i \qquad (5)$$

and

$$\Sigma_R = \sum_i \rho_i (\Sigma_R/\rho)_i \qquad (6)$$

Therefore, in this work, the (Σ_R) is calculated for the composites by using formula (6). The values of Σ_R / ρ (cm^2.g^{-1}) for various elements in the used composites were obtained from [7, 33-34]. The elemental composition of the composites C_1, C_2, C_3, C_4, C_5, C_6 and C_7, the partial densities and the calculated and measured Σ_R values are given in Table 4 and 5.

3. Results and calculations

The seven composites paste shields listed in Table 1 with different concentration of HDBE and BX mixed with 25% cement and 25% sand were used to test the contribution of this ratio content in paste to protect against gamma rays and fast neutrons. The composites under investigation have been studied and recently tested experimentally in our previous work [31].

The value of μ/ρ for the investigated composites (C_1, C_2, C_3, C_4, C_5, C_6 and C_7), are calculated at energies from 0.01 MeV to 100 MeV using the WinXCom program. The results had been listed in Table 3 and illustrated in Figs.1& 2. Generally, μ/ρ values are decreasing with increasing the photon energy. As shown in Table 3, it can be observed that, the calculated μ/ρ at energies 0.01–100 MeV for the composite C_6 are, generally, higher than all composites. This is attributed to the very strong dependence of photoelectric absorption on the elemental composition, the higher effective of atomic number and composites density.

In Figs. 1 & 2, the curves were divided into three regions according to the photon energy; in region (I), the dominant interaction is the photoelectric absorption, which is prevailing in the low energy range of about 0.01 to 0.1 MeV. It can be noticed that, the μ/ρ decreasing sharply with photon energy for all composites demonstrated. This is because cross section for this reaction varies approximately as Z^4/E^3 and μ/ρ depends on the elemental composition and consequently on the composites density. In region (II), an incoherent scattering (Compton scattering) of photon is dominant in the intermediate energy region of 0.1 to 8 MeV. The value of μ/ρ decreases slowly with increasing energy and are nearly the same for all composites. This is because of the dominance of the Compton scattering, which is depends only on the electron density per unit mass. In the case of high-energy region (III) (photon energy >10 MeV), the dominant process is the pair production. It can be seen that, the value of μ/ρ increase with increasing the photon energies for all composites demonstrated, which attribute to the successive collisions. Therefore, the photon energy will be decreased, which it can be absorbed and that is lead to increase μ/ρ.

For neutron shielding calculations, the data in Tables 4 and 5 produces the calculations of the effective removal cross-section for the seven composite past. As illustrated in Tables 2, 4 and 5, there is an evident relation between the calculated Σ_R/ρ values and borax concentration of the composites samples. The results can be biased on the interaction mechanisms of neutrons with the microscopic cross section of hydrogen and boron atoms. Since hydrogen, atoms display the major role of the slowing down mechanisms of fast neutrons (i.e.as hydrogen atoms is maximum the slowing down process is maximum), which enhances the neutron capture by boron and hence the removal cross-section. This could be attributed to the fact that, the composite C_6 is more riche with hydrogen and boron atoms relative to other composites demonstrated as shown in Table 2. In addition, the increasing of the concentration of boron atoms in the composite will enhance the neutron capture and hence the total (Σ_t) and removal cross section (Σ_R), therefore the shielding efficient will increase. This means that composite C_6 is the highest one in the field of fast neutron shielding demonstrated. In addition, the comparing data in table 6 were compared with different previous studies [7, 10, 14, 17-19] and a reasonable consensus for the attenuation parameter is found. In addition, the HVL is calculated and illustrated in Table 6. It can be noticed that, the composite C_6 has the lowest HVL as compared with all available shields.

Table 4. Calculation of the fast neutron effective removal cross-section for composites that have high concentration o

Elements	Σ_R/ρ (cm^2g^{-1})	C_1 $\rho = 1.78$		C_2 $\rho = 1.82$		C_3 $\rho = 1.85$	
		partial density (g cm^{-3})	Σ_R (cm^{-1})	partial density (g cm^{-3})	Σ_R (cm^{-1})	partial density (g cm^{-3})	Σ_R (cm^{-1})
H	0.5981	0.122002	0.07295672	0.119392	0.071396416	0.124339	0.074354423
B	0.0753	0.021983	0.00164873	0.036928	0.002769585	0.073667	0.005525025
C	0.0502	0.883948	0.04437419	0.7744135	0.038875382	0.651574	0.032708814
O	0.0405	0.262554	0.01063328	0.4220584	0.017093349	0.563325	0.022814663
Na	0.0341	0.053969	0.00184036	0.0735826	0.002509167	0.102675	0.003501218
Mg	0.0333	0.016264	0.00054159	0.0166257	0.000553636	0.016788	0.000559065
Al	0.0293	0.030883	0.00090487	0.0315588	0.000924673	0.031876	0.000933952
Si	0.0252	0.018850	0.00047503	0.0192738	0.0004857	0.019462	0.000490442
S	0.0277	0.041723	0.00115573	0.0426426	0.0011812	0.043068	0.001192984
Ca	0.0243	0.021449	0.00052121	0.0219314	0.000532923	0.022145	0.000538111
Fe	0.0214	0.052564	0.00112486	0.0537264	0.001149745	0.054261	0.001161175
K	0.0247	0.026878	0.00066389	0.0274638	0.000678356	0.027732	0.000684968
P	0.0283	0.049966	0.00141431	0.0510874	0.001445773	0.051578	0.001459657
Ti	0.0223	0.075486	0.00165921	0.0771134	0.001696495	0.077867	0.001713063
Calculated Σ_R			0.13991365		0.141292399		0.14763756
Measured Σ_R [31]			0.100±0.029		0.107 ± 0.03		0.112 ± 0.027

Table5. Calculation of the fast neutron effective removal cross-sections for composites that have high concentr

elements	Σ_R/ρ (cm^2g^{-1})	C_5, ρ = 1.98		C_6, ρ = 2.06		C
		partial density ($g\ cm^{-3}$)	Σ_R (cm^{-1})	partial density ($g\ cm^{-3}$)	Σ_R (cm^{-1})	partial den ($g\ cm^{-3}$
H	0.5981	0.115348	0.068978	0.125207	0.07487367	0.11843
B	0.0753	0.133459	0.010009	0.156169	0.01171265	0.16065
C	0.0502	0.402501	0.020206	0.292108	0.01466382	0.14786
O	0.0405	0.926348	0.037517	1.090976	0.04418453	1.13131
Na	0.0341	0.149163	0.005087	0.196400	0.00669725	0.32988
Mg	0.0333	0.018102	0.000603	0.018822	0.00062678	0.01899
Al	0.0293	0.034323	0.001006	0.035741	0.00104721	0.03606
Si	0.0252	0.021012	0.000530	0.021815	0.00054975	0.02202
S	0.0277	0.046465	0.001287	0.048286	0.00133753	0.04873
Ca	0.0243	0.023902	0.000581	0.024823	0.00060319	0.02506
Fe	0.0214	0.058411	0.001250	0.060832	0.00130180	0.06140
K	0.0247	0.029902	0.000739	0.031106	0.00076832	0.03138
P	0.0283	0.055686	0.001576	0.057824	0.00163643	0.05836
Ti	0.0223	0.083916	0.001871	0.087282	0.00192021	0.08810
Calculated Σ_R			0.151149		0.16192314	
Measured Σ_R[31]			0.148 ± 0.04		0.159 ± 0.035	

Table 6. Measured and calculated values of μ/ρ, HVL, MFP and Σ_R for seven composite past

Parameter	Composites number					
	C_1	C_2	C_3	C_4	C_5	C_6
$(\mu/\rho)_{cal}$	5.65E-02	5.81E-02	5.79 E-02	5.77 E-02	5.59 E-02	5.96 E-0
$(\mu/\rho)_{meas}$	4.65E-02 ±0.005	5.10E-02±0.006	5.48E-02±0.005	5.76E-02±0.005	6.07E-02±0.006	6.16E-02±0
HVL_{cal}	6.89	6.55	6.47	6.32	6.26	5.64
HVL_{meas}	8.35	7.45	6.68	6.36	5.78	5.46
MFP $(\lambda)_{cal}$	9.94	9.46	9.33	9.12	9.03	8.14
MFP $(\lambda)_{meas}$	12.05	10.75	9.9	9.17	8.33	7.87
$\Sigma_{R(calcu)}$	0.139	0.141	0.148	0.144	0.151	0.162
$\Sigma_{R(exp)}$	0.100±0.005	0.107±0.006	0.112±0.005	0.129±0.007	0.148±0.004	0.169±0.0

4. Conclusions

From this work, one can conclude that, the composite C_6 has the advantages among other composites demonstrated and the selection of a shielding material for fast neutrons and gamma ray depend on the elemental composites and the density of the composites. The demonstrated composites can attenuate the neutrons and gamma rays but with different efficiency. In addition, this composite has the advantages over all available shields of being; low thickness, low cost, light and durable to be formed and non-toxic. In addition, these shielding materials can be used in various fields such as research reactors, radiotherapy rooms, transporting the chemical isotopes and other different radiation sources

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