

Coconut Dust Gypsums Board Building Material for Shielding Radiation and Buildup Factors

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Abstract

The coconut dust gypsums were fabricated and investigated through shielding radiation properties, energy absorption buildup factor (EABF), and exposure buildup factor (EBF). The mass attenuation coefficient (μ_m) was investigated by using the Compton scattering technique at energy 662 keV and theoretical values of the mass attenuation coefficients were computed by using the WinXCom software program at different photon energies from 1 keV - 100 GeV. EABF and EBF values were computed by the Geometric Progression (G-P) fitting method at photon energies ranging between 0.015 and 15 MeV up to deep penetration of 40 mean free path (mfp). After the addition of coconut dust volume into gypsum board, it was found that μ_m values of the experiment and theory were generally in a good agreement. The results also indicated that the μ_m increased while the EABF and EBF decreased along with the increase in the coconut dust volume. The EABF and EBF values with photon energy and deep penetration for coconut dust gypsums were found at a minimum value, i.e., at low and high energy range whereas, at the intermediate energy range, it could become high. These results suggest that coconut dust gypsums can be used as shielding radiation building material.

Keywords: Buildup factors, Coconut dust, Gypsum, Shielding radiation, Exposure buildup factor, Geometric progression

Introduction

Recently, the use of radiations and radioisotopes has been increasing day-by-day in many fields, such as medicine, reactors, agriculture, food industry, space, and nuclear. The acknowledgement of the radiation dosimetry has become the favorite topic in physics radiation due to the danger of the radiation for human health, cell, and environment, causing refusals against ionizing radiation. This problem can be solved by 3 major methods namely distance, shielding, and time [1-4].

Gypsum is a basic and very useful material for shielding applications. The earliest known for centuries and used as a building material was in Anatolia around 6000 B.C. This material is being used for the objective of structuring of a building of nuclear facility construction, agriculture, industry, and direct shielding applications [5,6].

In 2001, Gerward developed the WinXCom program and widely used for estimated attenuation coefficient radiation of many materials such as glasses, concrete, rock, cement, and gypsum [1,5,14]. In

this context, the mass attenuation coefficient (μ_m) of coconut dust gypsums has been investigated in the energy 662 keV by the Compton scattering technique and computed using the WinXCom computer program. This work also includes a comparison of mass attenuation coefficients of coconut dust gypsums with ordinary concrete. The computation EABF and EBF values were using the G-P fitting method at energies range from 0.015 - 15 MeV up to deep penetration 40 mfp.

Materials and methods

Shielding radiation

Three different types of coconut dust gypsums were started by mixing gypsum, coconut dust, starch, and water, after mixing poured samples into mold, the composition of coconut dust gypsum samples as shown in **Table 1**.

Table 1 The compositions of coconut dust gypsums (grams).

Code	Gypsum (g)	Coconut dust (g)	Starch (g)	Water (g)
f1	69	1	10	20
f2	69	2	10	20
f3	69	3	10	20

The mass attenuation coefficient (μ_m) of coconut dust gypsums were investigated at the energy of γ -ray 662 keV. The energy of γ -ray has been obtained from ^{137}Cs radioactive sources. The investigation was acted using a well-calibrated γ -ray spectrometer that includes of 2" \times 2" NaI (TI) scintillation detector which has 8 % energy solution at 662 keV (BICRON model 2M2/2), with CANBERRA photomultiplier tube base model 802-5. A schematic diagram of the experimental setup was shown in **Figure 1**. The theoretical determination for mass attenuation coefficient values of the samples was calculated by the WinXCom program at energy 1 keV to 100 GeV.

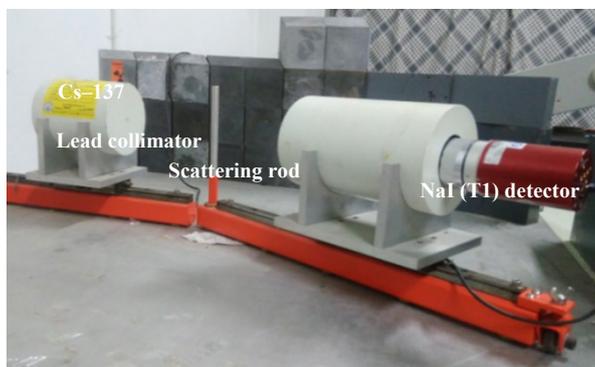


Figure 1 Experimental setup for transmission energy of 1 keV - 100GeV.

The determination of attenuation coefficient for γ -ray was made by investigating the transmitted radiation intensity pass through-thickness x as compared to incident radiation intensity I_0 . The linear attenuation coefficient (μ) was explained from exponential Beer-Lambert's law [7-9]:

$$I = I_0 \cdot e^{-\mu x} \quad (1)$$

The mass attenuation coefficients (μ_m) of mediums were computed using the similar formula [10,11]:

$$\mu_m = \sum_i w_i (\mu_m)_i \quad (2)$$

here, w_i is the weight fraction, μ_m is the mass attenuation coefficient of the i^{th} element.

Buildup factor

The buildup factors and G-P fitting parameters for coconut dust gypsums were computed from the equivalent atomic number (Z_{eq}) by logarithmic interpolation method. The calculation was operated by three steps:

1. Computation of equivalent atomic number (Z_{eq});
2. Computation of G-P fitting parameter using interpolation method;
3. Computation of buildup factors [12,15].

Z_{eq} is a single parameter which explains properties for coconut dust gypsums in terms of equivalent elements and were computed from the ratio of $(\mu_m)_{\text{Compton}}$ with $(\mu_m)_{\text{total}}$ at same photon energies, using the formula [12,13]:

$$Z_{\text{eq}} = \frac{Z_1(\log R_2 - \log R) + Z_2(\log R - \log R_1)}{\log R_2 - \log R_1} \quad (3)$$

where Z_1 and Z_2 are values of atomic numbers of elements according to ratios R_1 and R_2 , respectively. R is ratio $(\mu_m)_{\text{Compton}}/(\mu_m)_{\text{Total}}$ for coconut dust gypsums at the same energy. The parameters of G-P fitting are computed by the logarithmic interpolation method for Z_{eq} . The parameters of G-P fitting for elements were taken report by the standard reference database, the American Nuclear Society ANSI/ANS-6.4.3. For coconut dust gypsums were using the formula [12,13]:

$$P = \frac{P_1(\log Z_2 - \log Z_{\text{eq}}) + P_2(\log Z_{\text{eq}} - \log Z_1)}{\log Z_2 - \log Z_1} \quad (4)$$

where P_1 and P_2 are parameters value of G-P fitting like atomic numbers of Z_1 and Z_2 , respectively, at same energies. The parameters of G-P fitting of coconut dust gypsums were used to compute buildup factor as determined by [12,13]:

$$B(E, X) = 1 + \frac{b-1}{K-1} (K^x - 1), \quad K \neq 1 \quad (5)$$

$$B(K, X) = 1 + (b-1)x, \quad K = 1 \quad (6)$$

and

$$K(E, x) = cx^a + d \frac{\tanh\left(\frac{x}{X_K} - 2\right) - \tanh(-2)}{1 - \tanh(-2)}, \quad x \leq 40 \text{ mfp} \quad (7)$$

where E and x are incident photon energies and penetration depth in terms of mean free path (mfp), respectively., a , b , c , d , and X_K are G-P fitting parameters. K parameter with deep penetration indicates photon dose multiplication and adjusts in the configuration of the spectrum.

Results and discussion

Shielding radiation

The μ_m values for coconut dust gypsums were compared with ordinary concrete from simulation by the WinXcom program as shown in **Figure 2**. It was found that the μ_m value of f3 had the highest value and all samples had a higher value than ordinary concrete. These indicated that coconut dust gypsums had shielding radiation properties better than ordinary concrete and f3 had the best shielding radiation properties. From **Figure 2**, graphs are not continuous due to the absorption edge of Silicon (K 1.84×10^{-3} MeV), Sulfur (K 2.47×10^{-3} MeV), Potassium (K 3.61×10^{-3} MeV), Calcium (K 4.04×10^{-3} MeV), Titanium (K 4.97×10^{-3} MeV), Manganese (K 6.54×10^{-3} MeV), and Iron (K 7.11×10^{-3} MeV).

Table 2 The μ_m for experimental and theoretical of coconut dust gypsums (cm^2/g).

Energy (keV)	f1		f2		f3	
	$\mu_m(\text{th})$	$\mu_m(\text{ex})$	$\mu_m(\text{th})$	$\mu_m(\text{ex})$	$\mu_m(\text{th})$	$\mu_m(\text{ex})$
662.00	0.07735	0.07729	0.07735	0.07751	0.07737	0.07780

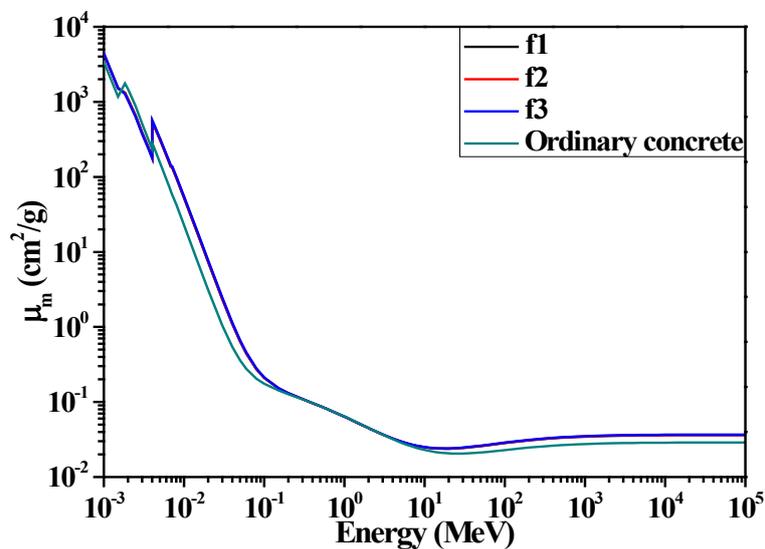
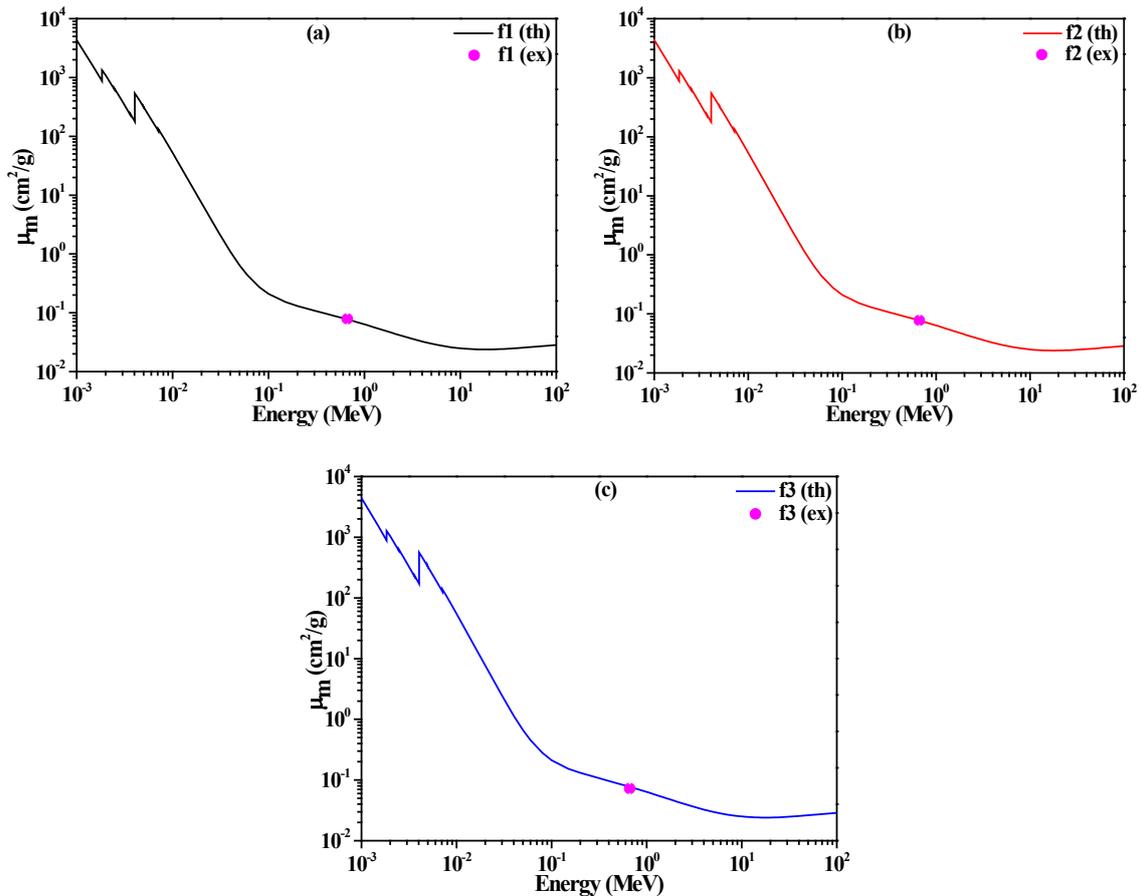


Figure 2 μ_m of coconut dust gypsums compared method using Compton scattering with ordinary concrete for photon technique.



Figures 3 (a) - (c) The comparison μ_m of coconut dust gypsums between experimental and theoretical at a photon energy of 662 keV.

The μ_m values from the experiment and theory were compared as seen in **Figures 3(a) - 3(c)**. The experiment used the Compton scattering technique to determine μ_m values at gamma ray energy 662 keV. The result indicated that μ_m values increase along with the increasing coconut dust volume, implying the better shielding properties in this energy, and it was observed that the μ_m values from experiment and theory were generally in a good agreement. As the interaction of the radiation with the medium depends on the material's volume, it is interesting to present μ_m as a function of coconut dust's volume. This is illustrated in **Figures 3(a) - 3(c)** (at the photon energy of 662 keV) where it can be seen that μ_m increases with an increase in coconut dust volume [8].

Buildup factor

Figure 4 gives equivalent atomic numbers (Z_{eq}) of shielding radiation materials at an energy range from 0.015 - 15 MeV. This figure exhibits Z_{eq} dependence on coconut dust volume in which Z_{eq} increases with increasing coconut dust volume.

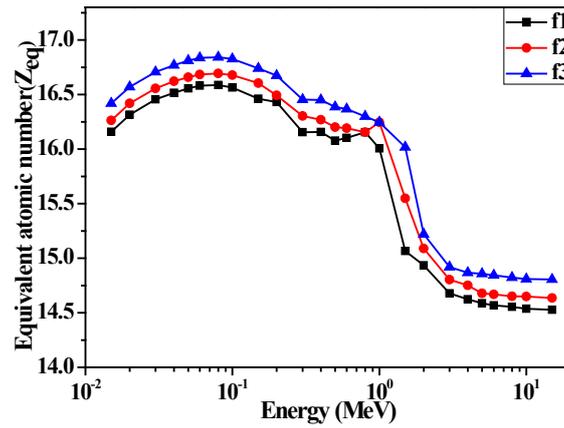
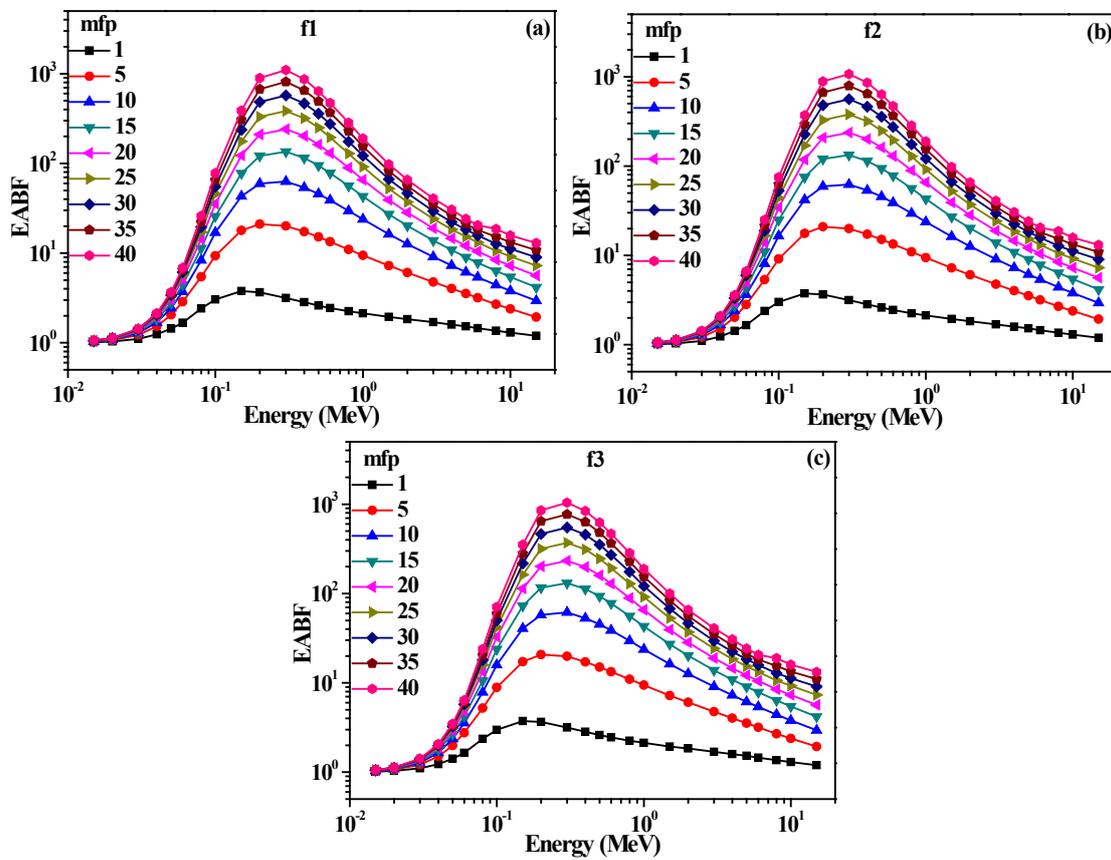
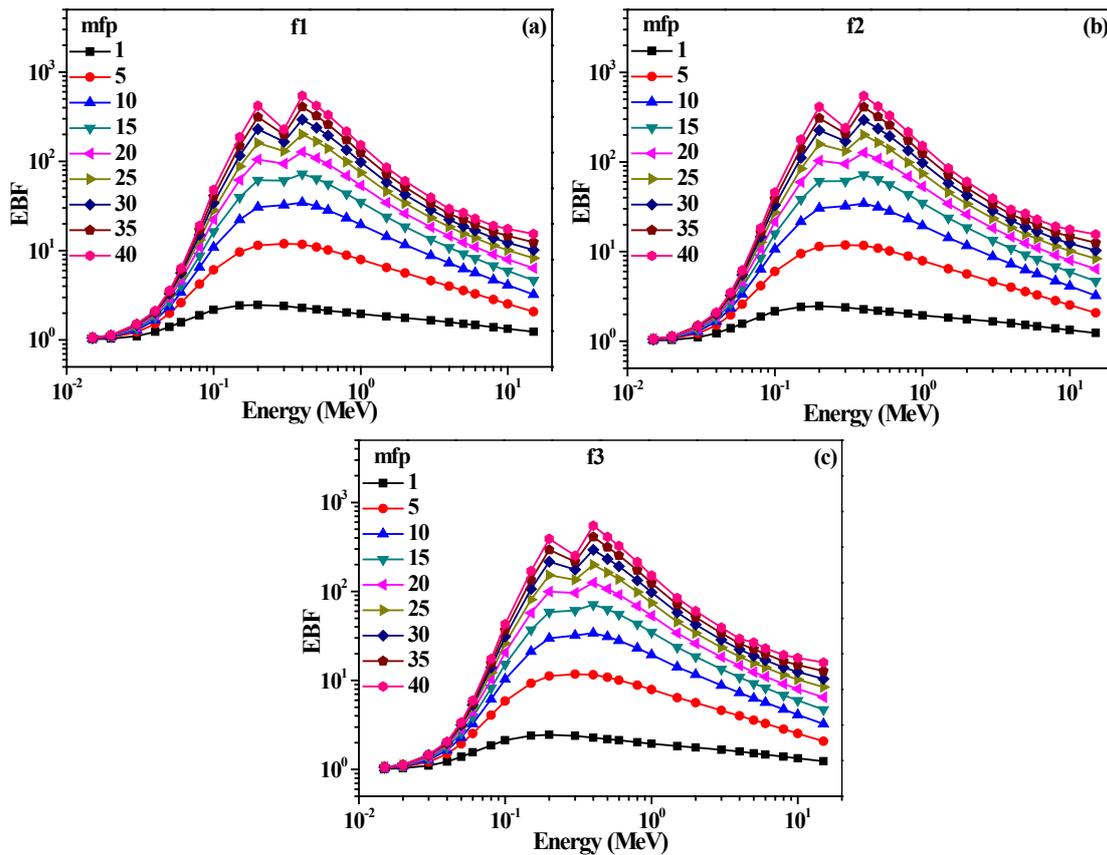


Figure 4 Z_{eq} of coconut dust gypsums.



Figures 5 (a) - (c) EABF with energy for gypsums at 1, 5, 10, 15, 20, 25, 30, 35 and 40 mfp, respectively.

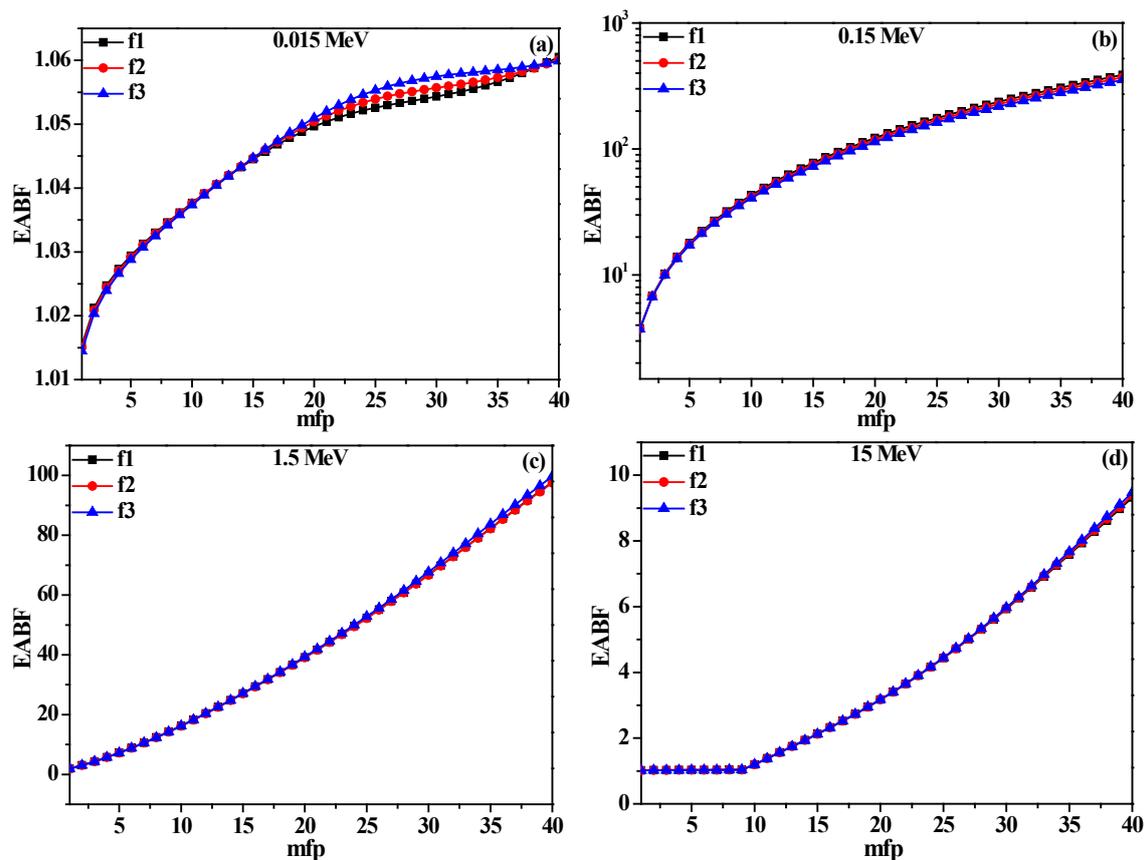


Figures 6 (a) - (c) EBF with energy for gypsums at 1, 5, 10, 15, 20, 25, 30, 35 and 40 mfp, respectively.

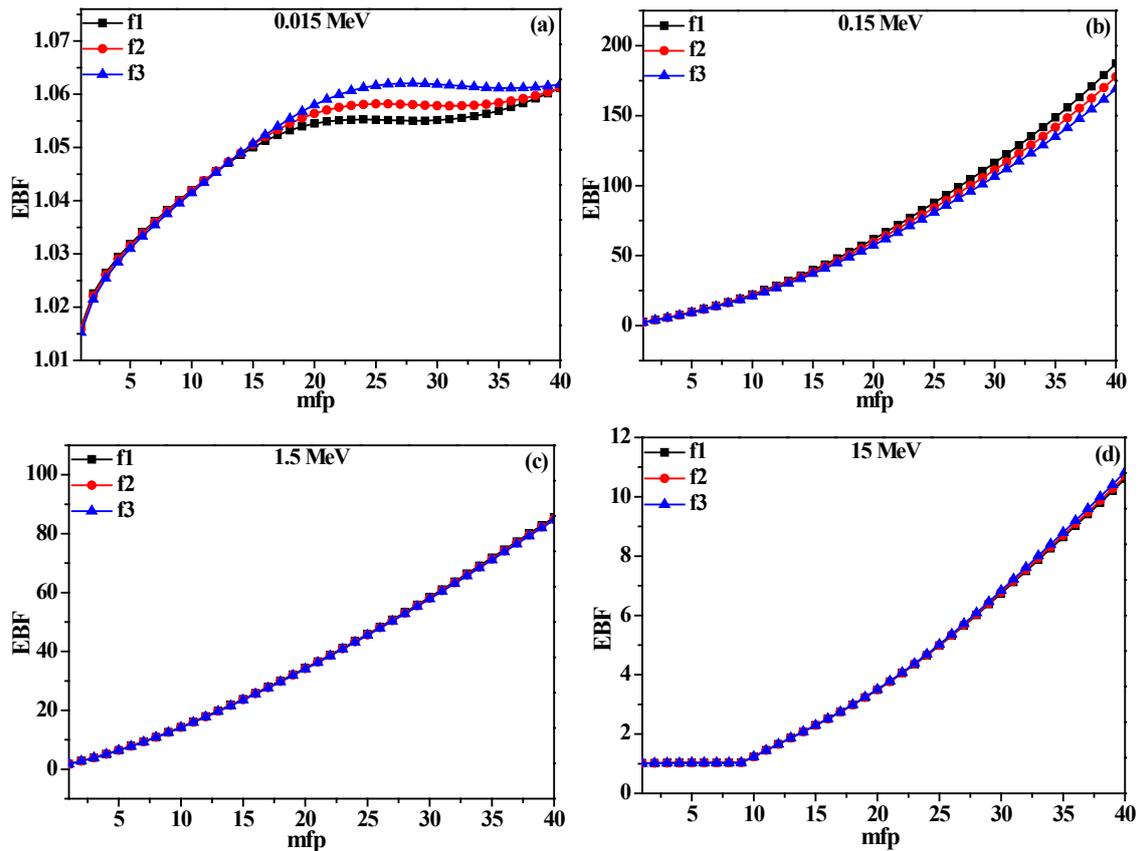
Figures 5(a) - 5(c) and **Figures 6(a) - 6(c)** exhibit the EABF and EBF with energies for coconut dust gypsums at 1, 5, 10, 15, 20, 25, 30, 35, and 40 mfp, respectively. The variation of the EABF and EBF with energies from 0.015 to 15.0 MeV, for coconut dust gypsums at the deep penetration of all mfp, are exhibited in the same trend of the EABF and EBF with energy. The variations of the EABF and EBF values of coconut dust gypsums with energy are shown in **Figures 5(a) - 5(c)** and **Figures 6(a) - 6(c)**. It was found that the EABF and EBF values of coconut dust gypsums shielding radiation had a minimum value at the low and high energy range, while they had a higher value in the intermediate energy range. The buildup factors in low energies range were small because these energies were absorbed completely by the photoelectric absorption effect, or removed completely, gradually increasing with energy because of the multiple scatterings of a photon by the Compton scattering technique at the intermediate energy range and lastly, it decreased again at the high energy range because of the pair production. The maximum energy, E_{max} , at which the EABF values were maximum for f1, f2, and f3, was 0.3 MeV. The EBF of f1, f2, and f3 had two peaks at 0.2 and 0.4 MeV because of the K-absorption edge of iron (Fe) composition elements in range and E_{max} for the EBF values was 0.4 MeV. The analysis disclosed that f3 was suitable for coconut dust gypsums shielding for photons as the low EABF and EBF values compared with other coconut dust gypsums for different energies were observed.

Figures 7(a) - 7(d) and **Figures 8(a) - 8(d)** displays the values of EABF and EBF with a deep penetration for coconut dust gypsums at 0.015, 0.15, 1.5, and 15 MeV energies, respectively. It was found that the EABF and EBF values of the coconut dust gypsums increased with the penetration depth initially. Both figures illustrate that at the low energy, the EABF and EBF are mfp loose. At the intermediate

energy, EABF and EBF increase in value and at the high energy, EABF and EBF again decrease in value. These can be discussed on the basis of the partial photon interaction processes. At the low energy range, buildup factors had small values because the photoelectric effect was the main interaction affecting photons to move fast, not allowing them to accumulate in the medium. Therefore, both values indicated the dependence on chemicals compositions for gypsum at the lower energy range. At the intermediate energy, the EABF and EBF had large values because the Compton scattering technique was dominant affecting photons to bring multiple scatterings and accumulate in the medium. Therefore, both values show complete independence on chemical compositions of gypsum at the intermediate energy range. At the high energy range, both values decreased because the pair production was dominant producing electron-positron pair [15,16]. Such process prevented photons from accumulating in the medium. From **Figures 7 and 8(b)**, it is evident that f3 had the greatest shielding effect.



Figures 7 (a) - (d) EABF with deep penetration for coconut dust gypsums at 0.015, 0.15, 1.5 and 15 MeV, respectively.



Figures 8 (a) - (d) EBF with penetration depth for coconut dust gypsums at 0.015, 0.15, 1.5 and 15 MeV, respectively.

Conclusions

γ -ray shielding properties of coconut dust gypsums were studied. Results of the mass attenuation coefficients increased along with an increase in the coconut dust gypsums volume and decreased along with an increase in the incident gamma ray energy and all samples had a higher value than ordinary concrete. These indicated that coconut dust gypsums had shielding radiation properties better than ordinary concrete. The sample materials were measured in terms of γ -ray, EABF, and EBF by the G-P fitting formula in energies region at 0.015 - 15 MeV up to a penetration depth of 40 mfp. Significant increases in EABF and EBF were observed in the sample materials at the energy of 0.4 MeV, where the Compton scattering technique was predominated, in the same way as EABF and EBF with a penetration depth of coconut dust gypsums at 0.015, 0.15, 1.5, and 15 MeV. The results suggested that the coconut dust gypsums that had more coconut dust was the greatest shielding γ -ray. These results encourage the use of coconut dust gypsums as shielding radiation building material.

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