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A Study of Gamma Ray Buildup Factor for Some Metal Oxide Mixed with Epoxy

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Abstract

In the present research, the buildup factors were assessed for samples made of composite materials from epoxy as the basis material and reinforcing materials as metal oxides, BeO, MgO, TeO3, and Bi2O3 in different weight ratios, 10, 20, 30, and 40%. These samples are cylindrical in shape with a diameter of 2.5 cm and a height of 2 cm, that is the same thickness for all samples and irradiation by energy equal to 0.662 MeV from cesium radioactive sources Cs-137, which have the activity 9.49 µci. The obtained buildup factors were used 2"×2" Thallium-doped Sodium Iodide NaI(Tl) detector for sample analysis and measurement. Study results show that buildup factors decreased while concentrations in the reinforcing materials increased, and an inverse relationship between the density or atomic number of the material and the buildup factor.

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1. Introduction

Energy that travels across space and the physical medium is called radiation, and it can be either ionizing or nonionizing according to energy. the sources of radiation either natural or industrial, Today, with technological development, the radiation using in many fields such as medical, food processing, space technology in addition to nuclear reactors etc. which cause hazards and significant harm to people close can be prevented and causing sickness and even fatality by penetrate and ionize cells which lead to destroy human cells' proteins, DNA, and other genetic material [1, 2]. Three fundamental preventive strategies from radiation hazards of radioactive sources: minimizing time, increasing distance, and shields: generally preferred for radiation protection Because it limits the restriction of time and distance by placing special materials between radiation sources and the person or object that needs to attenuate, absorb, or block the maximum part of incident radiation which transmission through the shield by two types of rays: interactive and without interactive. Nowadays, a lot of studies theoretical, experimental, and simulation studies dealt with many materials composite such as glasses, clays, alloys and heavy metal oxides for radiation risks shielding in different preparation ways with design based on the energy and type of the ionizing radiation In addition to the characteristics of the shield materials in the work on their chemical, physical, thermal, and mechanical stability Furthermore, optically transparent, recyclable, and environmentally friendly. Buildup factor for gamma ray play an important and a useful parameter calculating radiation shielding, absorbed dose and protection, which knows the radiation that penetrates the shield at the same point.[3-5] In the present work, the study of the buildup factor for samples consists of epoxy as based material and metal oxides such as Beryllium oxide (BeO), Magnesium Oxide (MgO), Tellurium Oxide (TeO_2), and Bismuth Oxides (Bi_2O_3) as reinforcing material in four different ratios 10%, 20%, 30%, and 40%.

2. Materials and Methods

The epoxy resin ($C_{18}H_{24}O_3$) has the chemical as shown in figure 1 utilized as the basic material has been blended with powders of composite materials (BeO, MgO, TeO_2, and Bi_2O_3) in various concentrations (10%, 20%, 30%, and 40%) and used as reinforcement materials to build a shield for attenuating gamma radiation using a delicate balance with a five-digit measurement accuracy, are measured and weighed. The combination was poured into a sample container which is measuring a 3 cm in diameter and 2 cm in thickness, the mixture is transferred to the ultrasonic device for about 15 minutes to complete the hardening process. This will ensure that the mixture is at its best and devoid of bubbles and blanks. The mixture needs to be left at room temperature to completely dry.

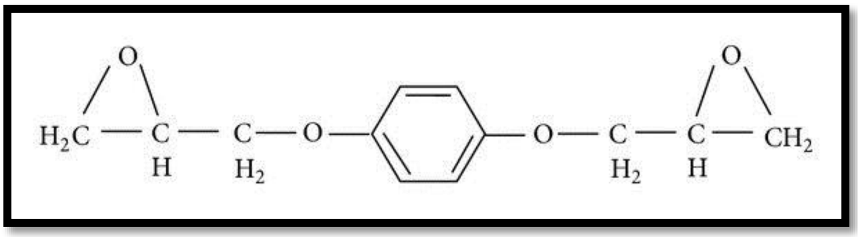

Figure 1. The chemical formula of the epoxy resin.

Using a collimator made of lead in the shape of a cylindrical with a diameter of 5 cm and a height of 5 cm, while 10 cm separated the source from the detector and using Cs-137 as radioactive source with activity 9.49 μci and a highly efficient detector of sodium iodide doped thallium NaI(Tl) (2"x2") with good geometric layout in figure 2.

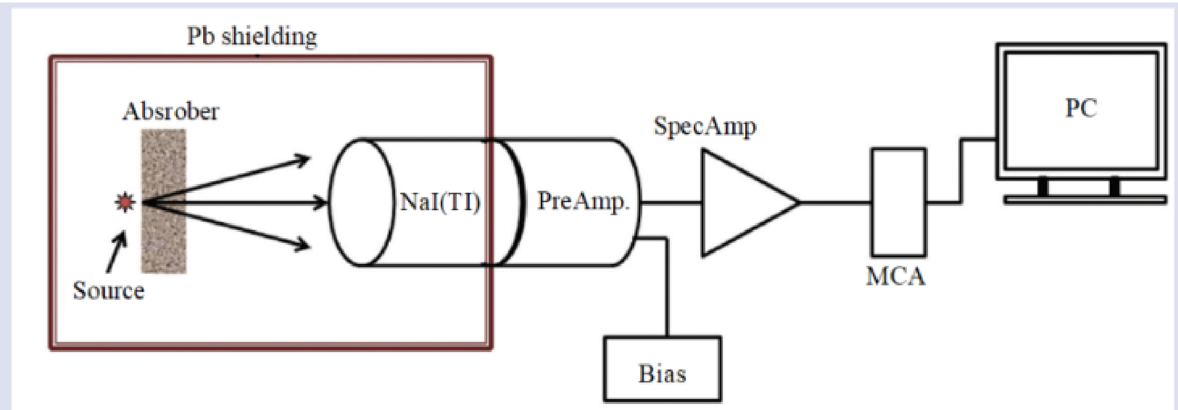

Figure 2. Diagram of the experimental setup.

3. Theory and Formula

The buildup factors are an important property and a correction factor in the γ-ray shielding fields that determine the proper thickness and dosimetry, this parameter depends on linear attenuation, energy of the photon, and thickness of the absorber. Buildup factor (B) shows the ratio of the total intensity beam at a given point to the unscattering intensity beam as equation 1:

$$B = \frac{\text{the total intensity beam}}{\text{the unscattering intensity beam}} \quad \dots (1)$$

As is known, the equation of Beer-Lambert shows can be used to measure the photon absorption potential of any substance by simulation and experimentation as equation 2:

$$I = I_{\circ} e^{-\mu x} \quad \dots (2)$$

where I and $I_{\circ}$ represents intensity of photon flux rays that are transmitted and incident and μ is the linear attenuation coefficient (LAC) of the absorber in cm^{-1} and X is the thickness of shield in cm. in figure (3) arrangement of schematic for geometry of the narrow beam shows the thickness of the shield which placed between the source and the detector, only photons that do not collide with the absorber can be detected in this circumstance by the detector. The following expression can be used to represent the narrow beam geometry [6,7].

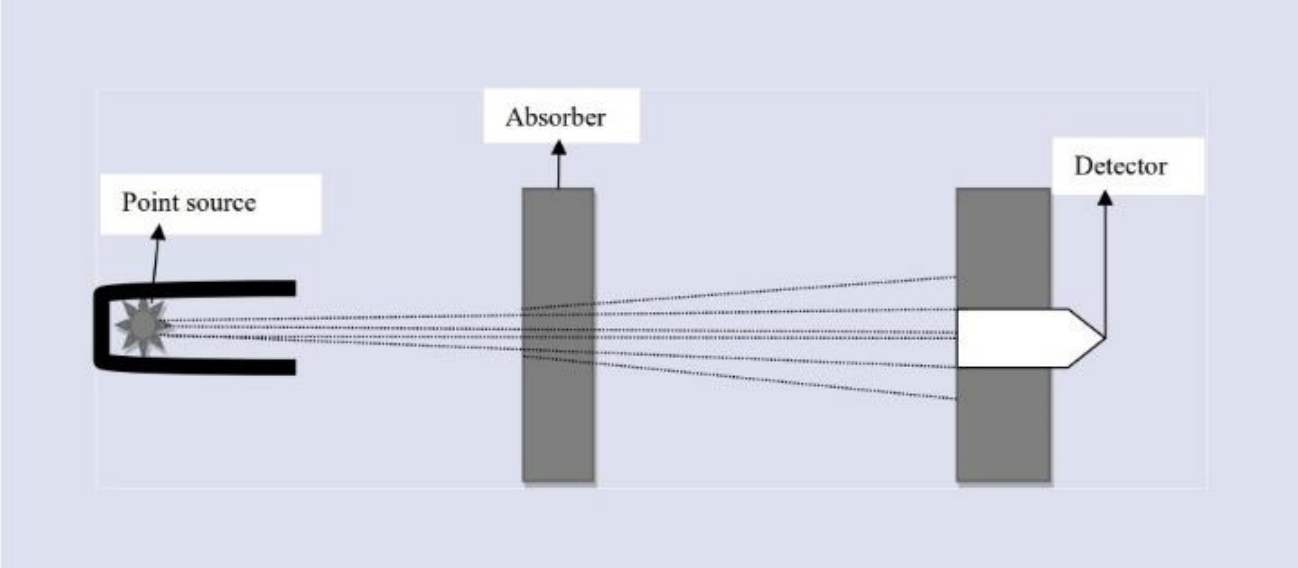

Figure 3. The good geometrical arrangement (narrow beam geometry)

The build-up factor is caused by two different forms of transmission rays through the shield: pair production and Compton scattering, which are two separate patterns resulting from photon interaction with matter, and unscattering rays, Figure (4) shown broad- beam geometry from scattering and unscattering rays in the shield are able to reach the detector and the expressionin for the broad-beam geometry in eq (3):

$$I = BI_{\circ}e^{-\mu x} \quad ...(3)$$

where B buildup factor

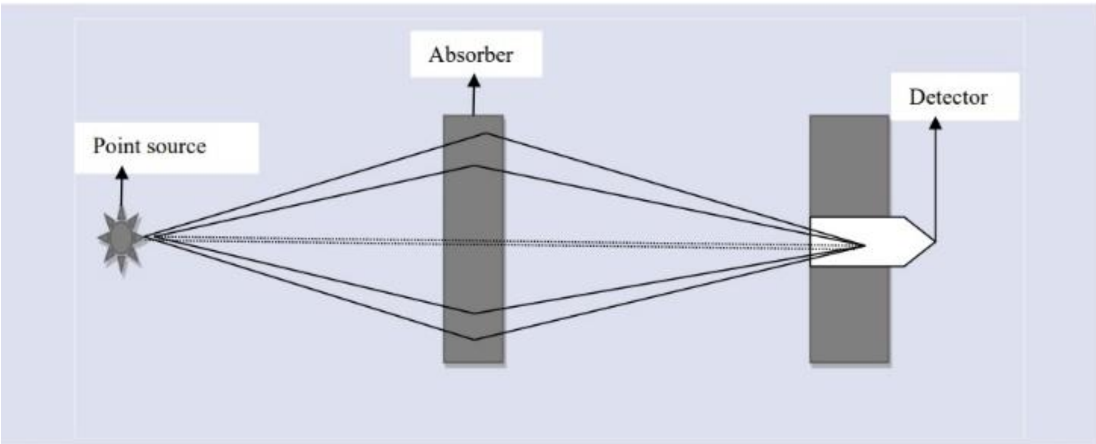

Figure 4. The bad geometrical arrangement (broad- beam geometry)

Consequently, using equations 2 and 3, the buildup factor can be determined using the relation shown below. [8-12]:

$$\boldsymbol{B = \frac{I_{bad\ geometry}}{I_{good\ geometry}}} \quad ...(4)$$

4. Results and Discussion

The radioactive source used in the experiment part is Cs-137 which irradiated gamma ray at energy 662 keV with activity 9.49 mci (25 mci at 1970) for 20 minutes, therefore, protection from gamma rays requires a shield with a high density of mass and by using materials with high atomic numbers and density. The results of buildup factor in this study for four different compounds as in Table 1.

Table 1. The values of Buildup factor using Cs-137 source.

materials	Concentration	I_{good}	I_{bad}	B
BeO	10%	0.830544	0.954734	1.149528
	20%	0.786611	0.889704	1.131059
	30%	0.771967	0.844119	1.093465
	40%	0.737448	0.78897	1.069866
MgO	10%	0.823222	0.91935	1.11677
	20%	0.79341	0.85145	1.073153
	30%	0.75	0.785145	1.04686
	40%	0.714435	0.733503	1.02669
TeO_2	10%	0.770921	0.802678	1.041194
	20%	0.703975	0.720115	1.022927
	30%	0.637029	0.618106	0.970295
	40%	0.591004	0.554989	0.939061
Bi_2O_3	10%	0.680962	0.66656	0.978851
	20%	0.595188	0.558177	0.937815
	30%	0.492678	0.426841	0.866369
	40%	0.375523	0.313357	0.834454

In figure 5 showed the relationship of buildup factor as a function with concentrations of metal oxide which explain by increasing the concentrations of reinforcement material (BeO, MgO, TeO_3 and Bi_2O_3) leads to decrease in the buildup factor which it Indicates the possibility of using composite materials as attenuation for the gamma rays because of the absorption of radiation is higher in the metals from the polymer to the change of the polymer properties which that the polymer is not suitable alone to use it as a shield, therefore, we note that the lowest value of the buildup factor is at the highest concentration of each metal, then the values of the buildup factor decrease with increasing concentrations of the compound in the polymer, and this indicates an improvement in the properties of the shield with increasing concentrations to the polymer because the shield's density has increased as in Figure (6) which shows the inverse relationship between the density of the material and the buildup factor.

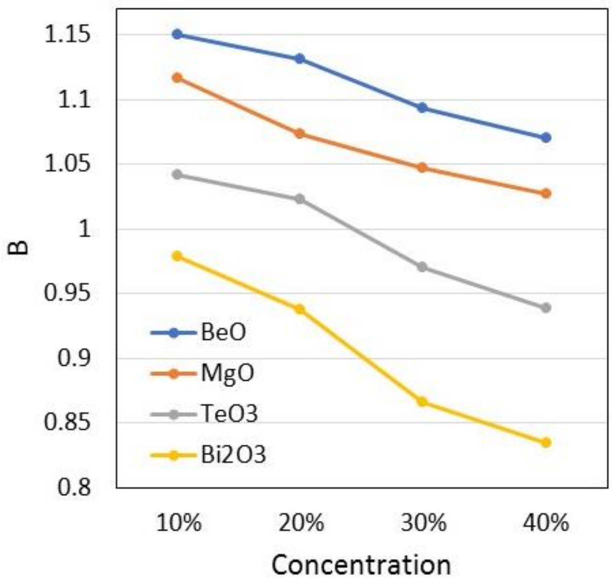

Figure 5. Correlation for the buildup factor and various composite material concentrations for the reinforcing material

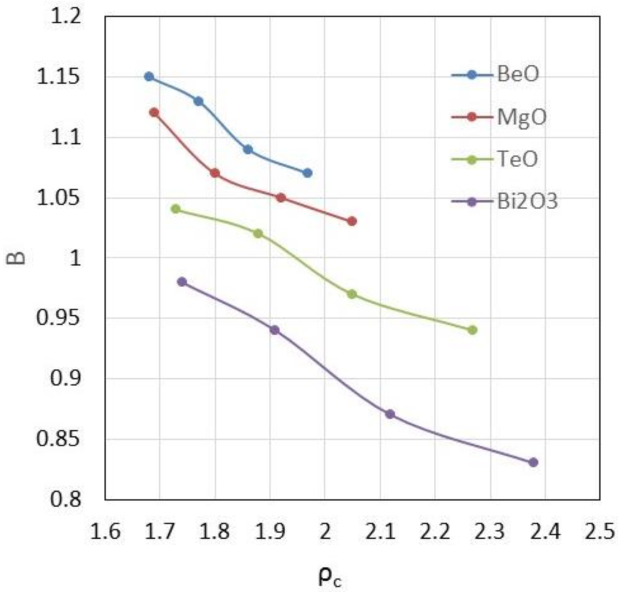

Figure 6. The behaver of Buildup factor (B) with density of compound for shield (ρ_c).

The buildup factor depends on the atomic number, so the figure (7) shows the relationship between the values of the buildup factor and the atomic number of the compounds used in preparing the shields in an inverse relationship. The higher the atomic number of the compounds, the values of the buildup factor decrease because low atomic numbers scatter photons more than high atomic numbers.

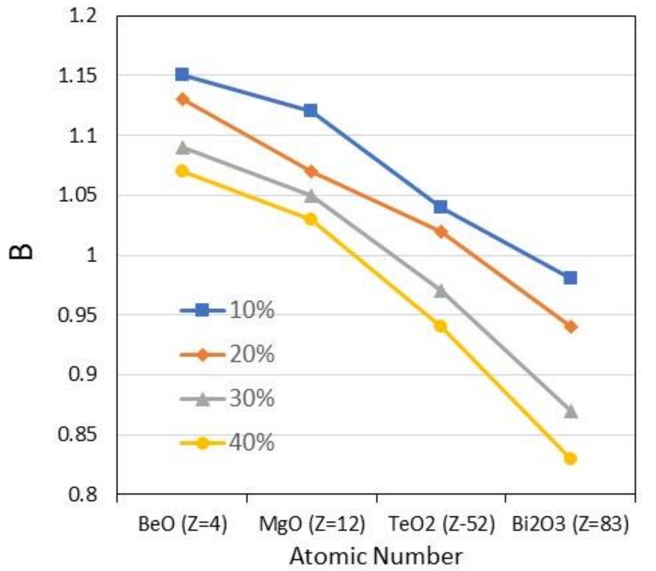

Figure 7. The behaver of Buildup factor (B) with atomic number of compounds.

5. Conclusions

In this research, buildup factor of gamma ray has been investigated and discussed at 662 keV from Cs-137 source and fixed thickness for composite materials (epoxy + metal oxide) with lighter and less expensive materials, the results for good-beam geometry values less than bad-beam geometry values. This led to the buildup factor decrease with increased of concentration of the reinforcing materials which is noticed that the buildup factor decreases with increasing in the atomic number for absorbers or density of samples for shield.

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