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**Shawkat I. Jubair**

*Department of Physics,*
*College of Science,*
*University of Baghdad,*
*Baghdad, Iraq*

# Calculation of Buildup Factors for Ceramic Materials

***The aim of this research is to obtain a composite material that can be used for the shielding against gamma rays utilized in many scientific, industrial and medical applications as well as protect the environment and people from the risk of radiation. In other word measured and determine the amount of shielding required to provide personal protection and environmental with lowest costs and appropriate selecting materials to reduce radiation doses in industrial facilities and surrounding areas.***

***Also in medical field, build up factor contributes to determine the amount of radiation dose reach to tumors tissue. So that the buildup factor for ceramic plates manufactured for this purpose was calculated, by using gamma-ray spectroscopy, and sheets of lead as standard material.***

***Keywords***: Gamma attenuation, Composites, Ceramic, Buildup Factor
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## 1. Introduction

In response to the requirements of development and industrial progress which is moving toward improving the performance of the product in terms of design, manufacturing and low cost. In the field of radiation protection the shielding materials protected from gamma radiation, such as concrete, lead, requires large blocks and then high costs. So the composite material help to solve the problem of shielding, these composite material have properties of multiple commensurate with many industrial applications. Due to their property, that combines characteristics of two or more by passing the misdeeds of each material, in addition, it has the ability to control their properties, both by the type and ratios of component materials or through the design and methods of manufacture, therefore these materials regarded an important material among different engineering materials.

In principle, one's dose in the vicinity of an external radiation source can be reduced by increasing the distance from the source, by minimizing the time of exposure, and by the use of shielding. Distance is often employed simply and effectively. For example, tongs are used to handle radioactive source in order to minimize the dose to the hands as well as the rest of the body. Limiting the duration of an exposure significantly is not always feasible, because a certain amount of time is usually required to perform a given task. Sometimes, though, practice runs before-hand without the source can reduce exposure times when an actual job is carried out [1].

While distance and time factors can be employed advantageously in external radiation protection, shielding provides a more reliable way of limiting personal exposure by limiting the dose rate. In principle, shielding alone can be used to reduce dose rates to desired levels. In practice, however, the amount of shielding employed will depend on a balancing of practical necessities such as cost and the benefit expected, where ceramic available cheap and friend for environment.

The thickness of the shielding required for attenuated the gamma photons depends on the geometrical arrangement for the source and the detector which is used to detect the shielded beam (I) and the initial beam ($I_o$ ) or depend on the buildup factors which are depends on the geometry arranges.

When gamma radiation is incident on a finite thickness of material, there exist some probabilities that the radiation will interact in the material and be attenuated. In some instances a photon may interact by the photoelectric effect, Compton scattering and pair production. Any of the common gamma interaction processes may result in secondary photons that have a finite probability of reaching the dose point of interest - inside or outside the attenuating materials.

The extent to which such secondary photons add to the flounce at the dose point is usually described as build up factors [2].

The buildup factor is defined by the ratio of the total radiation quantity at any point to the radiation quantity of radiation reaching the point without any collision. Many theoretical formula of building up factors were presented for the interpolation at arbitrary thickness of shielding materials. In the formula, the geometrical, progression approximation is well known to produce the buildup factors in the wide energy range of various materials and thickness with good accuracy. [3]

Buildup factors for monoenergetic source in infinite media have been calculated several times for various materials in the past 50 years, [4-7], however, only a few experimental results are known.

Therefore this work presents the buildup factors for (Ceramic and Leads) up to 5 mean free path (mfp) for (0.662 MeV photons) by using experimental work.

## 2. Theory

When a narrow parallel of photons passes though relatively thin shield, Fig. (1), the relative intensity of monoenergetic photons transmitted without interaction through a shield of thickness is:

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

where $I$ and $I_0$ are the shielded and initial beam intensities, respectively, $\mu$ is the linear attenuation coefficient (in $cm^{-1}$), and $x$ is the shield thickness in (cm)

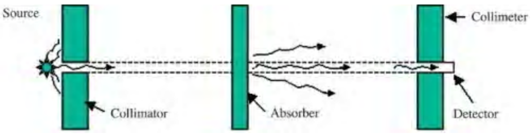

**Fig. (1) Measurement of the attenuation of gamma radiation under conditions of good geometry**

Ideally, the beam should be well collimated, and the source should be as far away as possible from the detector. The absorber should be midway between the source and the detector, and it should be thin enough so that the likelihood of a second interaction between a photon already scattered by the absorber and the absorber is negligible. In addition, there should be no scattering material in the vicinity of the detector

The linear attenuation coefficient can be considered as the fraction of photons that interact with the shielding medium per centimeter of shielding. It is also known as narrow beam conditions because the source and detector are assumed to be collimated and the measurement made at a short distance [8].

If the incident beam is broad (as shown in Fig. 2), then the measured intensity will be greater than that described by Eq. (1) because scattered photons will also be detected. Such conditions usually apply to the shields required for protection from gamma-ray sources. The increased transmission of photon intensity over the measured in good geometry can be taken into account

$$\frac{I}{I_0} = Be^{-\mu x} \qquad (2)$$

where $B$ is the buildup factor for one energy at the shield thickness $x$

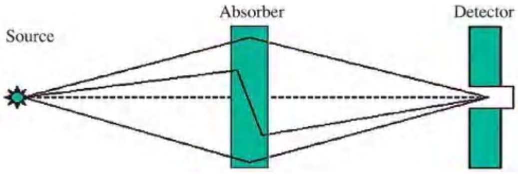

**Fig. (2) Gamma radiation attenuation under conditions of broad beam geometry showing the effect of photons scattered into the detector**

This formula attempts to estimate the correct number of scattered photons that reach the detector (closest estimate) by using a correction factor to add in the Compton scatter and pair production photons that are ignored by the linear attenuation coefficient formula. Therefore, the value of B can be obtained by dividing Eq. (2) by Eq. (1).

## 3. Experiment

Figure (3) shows the block diagram for the electronic system which used in this study and its consists of the following units: scintillation detector NaI(Tl) with dimensions 2″×2″, preamplifier (ORTEC) and MCA.

The materials which used as absorbers are blocks from lead material and ceramics slabs. Ceramic slabs made from Iraqi Flint clay consists mainly from alumina and silica, table (1) shows the chemical composition for Flint. The ionic alumina bonds absorbed gamma ray energy more than others bonds.

These slabs were shaped by hydraulic pressing with spherical die, then sintering with temperature by kiln at 1200°C have density (1-1.47) $gm/cm^3$, thickness (3.1-4.55) mm with diameter (4.1-4.98) cm.

The radioactive source was used in this study is disc shape of Cs-137 which emits gamma photons of 0.662 MeV energy and the activity is 20 μCi.

**Table (1) Chemical composition for Flint**

| Mineral | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | TiO | CaO | MgO | $Na_2O$ | $K_2O$ | L.O.I |
|---|---|---|---|---|---|---|---|---|---|
| Percent | 47 | 34 | 0.5 | 2 | 0.6 | 0.3 | 0.46 | 0.09 | 15 |

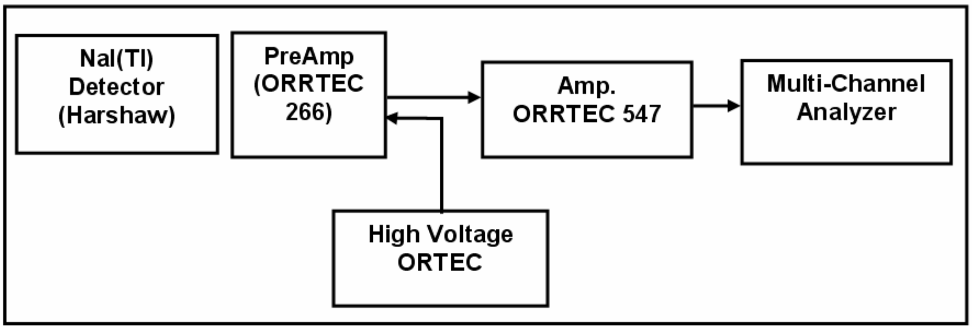

Fig. (3) The block diagram of the Electronic detection system

## 4. Results and Discussion

In the case of carrying out the shielding calculation for the radiation-shielding ceramic plates, a lead equivalent is generally used. In other words, first, the transmission of lead should be revealed. The data of transmission and build-up factor B of lead and ceramic is described in table (2).

Figures (4) and (5) show the relationship between ln $I/I_o$ versus the thicknesses of slabs of ceramic and lead, from Fig. (4), the linear attenuation coefficient for ceramic was obtained (0.0966 $cm^{-1}$), and from Fig. (5), the experimental attenuation coefficient for lead was obtained (1.0244 $cm^{-1}$).

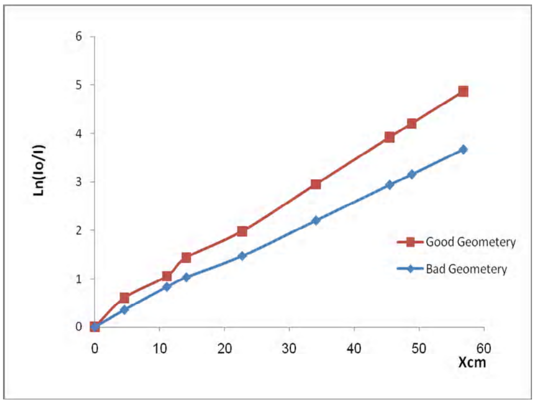

Fig. (4) Logarithm of the intensity versus thickness of ceramic for good and bad geometry

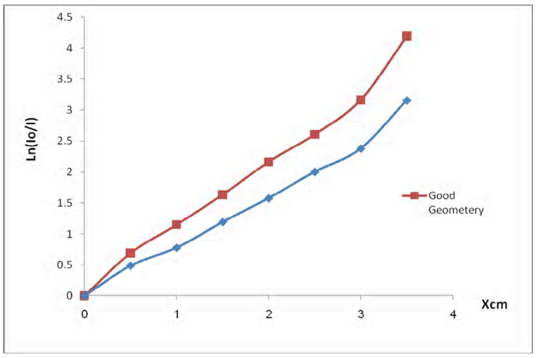

Fig. (5) Logarithm of the intensity versus thickness of lead for good and bad geometry

Table (2) values of mean free path, counts rate per (1000) s, for good and bad geometry and build up factors, for lead and ceramic materials

| Lead | | | | |
|---|---|---|---|---|
| μx Experimental | μx Theoretical | $N_{Bad}$ | $N_{Good}$ | Buildup Factor |
| 0 | 0 | 53285 | 5859 | 1.0000 |
| 0.484 | 0.554 | 32655 | 2927 | 1.2267 |
| 0.968 | 1.109 | 24404 | 1859 | 1.4434 |
| 1.452 | 1.663 | 16167 | 1142 | 1.5566 |
| 1.936 | 2.217 | 10983 | 672 | 1.7970 |
| 2.420 | 2.772 | 7171 | 433 | 1.8210 |
| 3.073 | 3.324 | 4937 | 247 | 2.1980 |
| 4.098 | 4.436 | 2255 | 89 | 2.7840 |
| | | | | |

| Ceramic | | | | |
|---|---|---|---|---|
| μx Experimental | | $N_{Bad}$ | $N_{Good}$ | Buildup Factor |
| 0 | | 53285 | 5859 | 1.0000 |
| 0.390 | | 37385 | 3203 | 1.2834 |
| 0.946 | | 23120 | 2031 | 1.2517 |
| 1.200 | | 18928 | 1385 | 1.5027 |
| 1.932 | | 12175 | 803 | 1.6666 |
| 2.898 | | 5844 | 305 | 2.1071 |
| 3.864 | | 2805 | 116 | 2.6588 |
| 4.154 | | 2250 | 87 | 2.8436 |

For comparison between this work and theoretical calculated, the values of theoretical linear attenuation coefficient for lead for 0.662 MeV energy obtained from [7] Fig. (6) (1.108 $cm^{-1}$). The percentage error ratio of attenuation coefficient for lead is 7.5%.

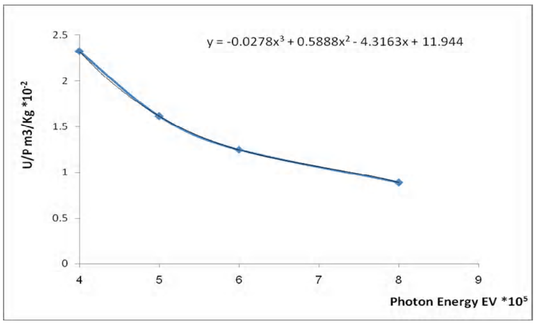

Fig. (6) Mass attenuation coefficients for lead as a function of photon energy [8]

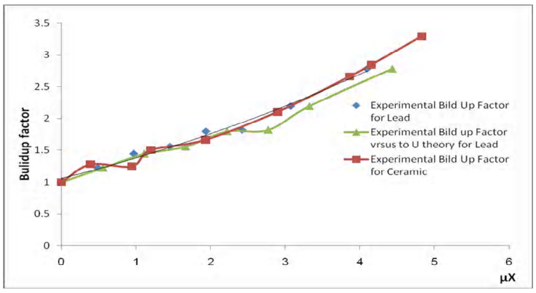

**Fig. (7) Buildup factors, B in lead and ceramic as function of the number of relaxation lengths, μx**

## 5. Conclusions

The first object of the present work is to provide a radiation-shielding ceramic capable of ensuring appropriate lightness and easier to dealing with it in radiotherapy, in addition to ensuring sufficient radiation-shielding ability. In other words, it is extremely important that the radiation-shielding means for the therapy ensures sufficient radiation-shielding ability and sufficient relaxability to prevent the body from directly being exposed to gamma rays while a doctor precisely confirm the complexion or the like of the subject

For the shielding performance, a plate thickness at which the transmission of the ceramic and the transmission of lead against a direct ray become equal is represented by a parameter of a lead equivalent. If the gamma ray (direct ray) of the ceramic of 10mm in thickness has a gamma-ray attenuation rate of 50% and lead of 3mm in thickness has a gamma-ray attenuation rate of 50%, then the ceramic of 10mm in thickness has a shielding ability of 3mm Pb (3mm equivalent), Fig.(7).

Therefore the ceramic material can be used as shielding barrier or a shielding protection screen against gamma rays. It is the actual condition that a matter of how to optimize the basic composition of ceramic for properly shielding the gamma rays emitted from the subject and for properly lightness, cheaper, available material and friend of environment to use it in the therapy.

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