Dependence of gamma-ray absorption coefficient on the size of lead particle

*Hayder S. Hussain** *Abdel hussain A.Al-Bayati**
*Harith I. Jaffer**

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Abstract:

In this study, dependence of gamma-ray absorption coefficient on the size of Pb particle size ranging from 200μm up to 2.5mm, using different weights of each particle size. The results show that gamma-ray attenuation coefficient is inversely proportional with the size of Pb particle size due to the reduction of the spaces between the lead particles.

Key words: gamma-ray, absorption coefficient, lead particle

Introduction:

Radiation shielding commonly used to protect medical patients and workers from exposure to direct and secondary radiation during diagnostic imaging in hospitals, clinics and dental offices. The effectiveness of radiation shielding varies significantly with the attenuation coefficients of the constituent materials, the thickness of the material and the energy spectrum of the radiation.

To insure total safety, all radioactive materials in the laboratory or place of work should be surrounded by sufficiently thick shielding material such that the radiation in neighboring work areas is kept at minimum permissible levels. This quantity of shielding is determined by the material chosen. The choice of shielding materials and the design of the shield depends on the type of radiation and its intensity. While certain materials are better suited than others for a given type of radiation, cost usually limits the choice of shielding to a few readily available materials. The most used are lead, iron and steel. Lead is often used because of its high atomic number and density. As well, it is soft and malleable and easily cast into various forms. Thus, radiation shielding aprons and coverings have been manufactured from lead powder-loaded polymer or elastomeric sheets. So we must know the best particle size of lead that can be used for shielding garments, which include some of the lead powders imbedded in natural rubber or various polymers.

Limiting Occupational Exposure:

There are three methods of reducing external exposure related to time, distance and shielding.

1. Time: Minimize the time spent in the vicinity of a source of radiation. Work efficiently, but do not rush.

2. Distance: The exposure dose is inversely proportional with the distance far away from the radiation some maintain as practical. Therefore increasing the distance far away from the radiation some reducing the exposure dose to minimum.

3. Shielding: When time and distance alone are not sufficient, shielding is usually used. Shields take many forms:

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

Lead aprons, syringe shields, vial shields, countertop shields (often with leaded glass), fixed and portable (on casters) lead barriers, as well as thinner shield of plastic that may be used for Beta-emitting and low-energy gamma-emitting sources.

The use of lead or other dense materials as shielding for beta particles is discourage because the dose will be increased owing to the bermsstrahlung effect [1]. So, we must use material with low Z before using lead.

Several more recent studies using clinical beams have examined different aspects of the attenuation properties of some commercial radiation aprons. For example, the study by Christodoulou et al [2] combines observations of inconsistencies in shielding performance with recommendations to improve standardized methods for acceptance testing. McCaffrey et al [3] studied the attenuating properties of several types of lead (Pb)- based and non-Pb radiation shielding materials. Gurdeep et al [4] have been measured the mass attenuation coefficient of 662keV gamma rays in the extended media of Bakelite and Perspex under different collimation conditions.

Theory and Evaluation:

The attenuation of gamma-ray when they pass through an absorber of thickness (α) is expressed by the exponential law.

$$N(\alpha)=N(o).e^{-\mu\alpha} \qquad (1)$$

where $N(\alpha)$ is the net impulse counting rate which is transmitted after absorption in the absorber, and N(o) is the impulse counting rate when no absorption takes place; μ is the absorption coefficient of the absorber material and depends on the energy of gamma quanta.

The absorption of gamma-rays is brought about by three independent effects: the Compton effect, the photoelectric effect and pair formation. The transmitted gamma-rays will in the main be those which pass through without any interactions at all. The relative contributions of these three effects to total absorption, depends primarily on the energy of the quanta and the atomic number of the absorber. We can therefore expect to find that the transmitted intensity of radiation $I(\alpha)$, which gets through the absorber, will be less than the incident intensity I(o), that is:

$$I(\alpha)<I(o) \qquad (2)$$

But by how much one can ask. Before we consider this let us denote the difference between $I(\alpha)$ and I(o) as $\triangle I$, that is:

$$\triangle I = I(o)-I(\alpha) \qquad (3)$$

Materials and Methods:

As stated earlier, the property of the shield material of the most significance in preventing this penetration is its density. Lead enjoys the advantage of being the densest of any commonly available material.

Material used:

1- Shot/Ball lead: lead shot is small balls of lead, traditionally made using a shot is used for a variety of purposes. Shot comes in two sizes: 1mm and 2.5mm.

2- Lead powder: lead powder incorporated into a plasticizer is added to plastics to form sheets of lead loaded plastic. Powder comes into two sizes: 200µm and 500µm so this material can be used to make radiation protective clothing and aprons for the medical, scientific and nuclear industries.

Measurement of count Rate:

The ^{137}Cs point source of strength (4.686µCi) per pared and supplied by Radiation Protection Center. Also, the experimental setup used for the present measurement, with available software Genie-2000 plat form, under windows NT/2000 supported. The supporting software extends the capabilities of the system to meet a wide range of application requirements.

In this arrangement there is a provision to increase the absorber weight up to 200gm. The count was measured for each weight with one minute for each of about four different weights, and for four different sizes of Pb powder and shots. While, the Pb sheet is exemplar measure as shown in Table (1).

Results and Discussion:
Effect of particles size:

Attenuation testing was performed for the four different sizes of lead. An initial series of measurements were made with 50gm weight of Pb sheets, stacked to provide the attenuation values for each size of Pb as represent in Table (1).

Table (1):

Pb weight in (gm)	Count rate 1min of Pb sizes				
	sheets	200µm	500µm	1mm	2.5mm
50	2670	3329	6758	7071	9419
100	1654	2844	5014	5376	6066
150	986	1134	3242	4319	5111
200	609	892	2005	3442	3934

From Table (1) we find that, the results of lead powder with size 200um approach to Pb sheets, while increasing Pb size will increase the difference in results. So, we can conclude that, whenever Pb size decrease as possible question, the results will verge on Pb sheets results.

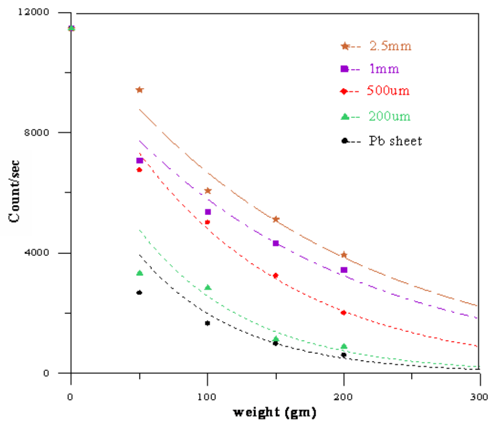


Fig. (1): Shows the relation between the count rate as a function of Pb weight.

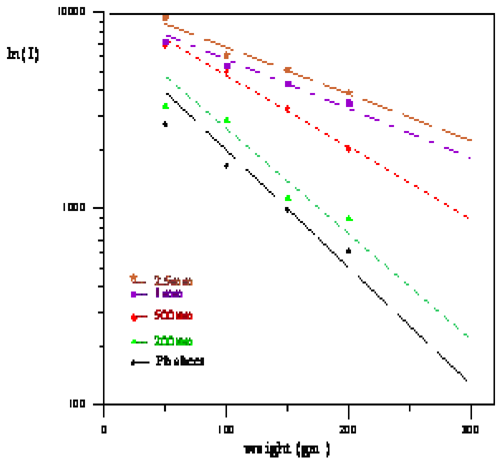


Fig.(2): Shows the relation between ℓn(I) as afunction of Pb weight.

From the regression lines from the measured values in figure (2) applying the exponential expression:

$N = N_o\, e^{-\mu x}$ or : $I = I_o\, e^{-\mu x}$

We obtain the value of µ for each sample $\mu_1, \mu_2, \ldots, \mu_5$ for the exponent. where µ is the absorption coefficient of the absorber material, and depends on the energy of the gamma quantum and the atomic number of the absorber.

As the energy of gamma quantum and the atomic number of the absorber are the same for all samples, then we could use the weight of sample, apposition the distance of the material absorbed.

were the linear Attenuation Coefficient $\mu \equiv cm^{-1}$
and the mass Attenuation Coefficient $\mu_m \equiv g^{-1}cm^2$

So that by division the mass attenuation coefficient (μ_m) with the plane geometry of the absorber A, we shall get:

$$\frac{\mu_m}{A}=\mu_g \qquad (4)$$

which can be shakes from figure (2).

The first point to not from figure (2), is that the Attenuation Coefficient increases as the size particle of the absorbers decreases. For example it increases from a very small value of ($0.005499gm^{-1}$) for (2.5mm) size to ($0.0123668gm^{-1}$) for (200μm) size approach to the sheet value ($0.0137319gm^{-1}$).

We can gain an appreciation of why this is, so from figure (3) and (4), the figures elucidate a big particle size absorber, which have a large blank between particles and the small particle size which have small blanks between particles. When the incident radiation beam enters each absorber the particles of small size present larger targets for the radiation to strike and hence the chance for interaction via the Photoelectric and Compton effects is relatively high. The attenuation should therefore be relatively large.

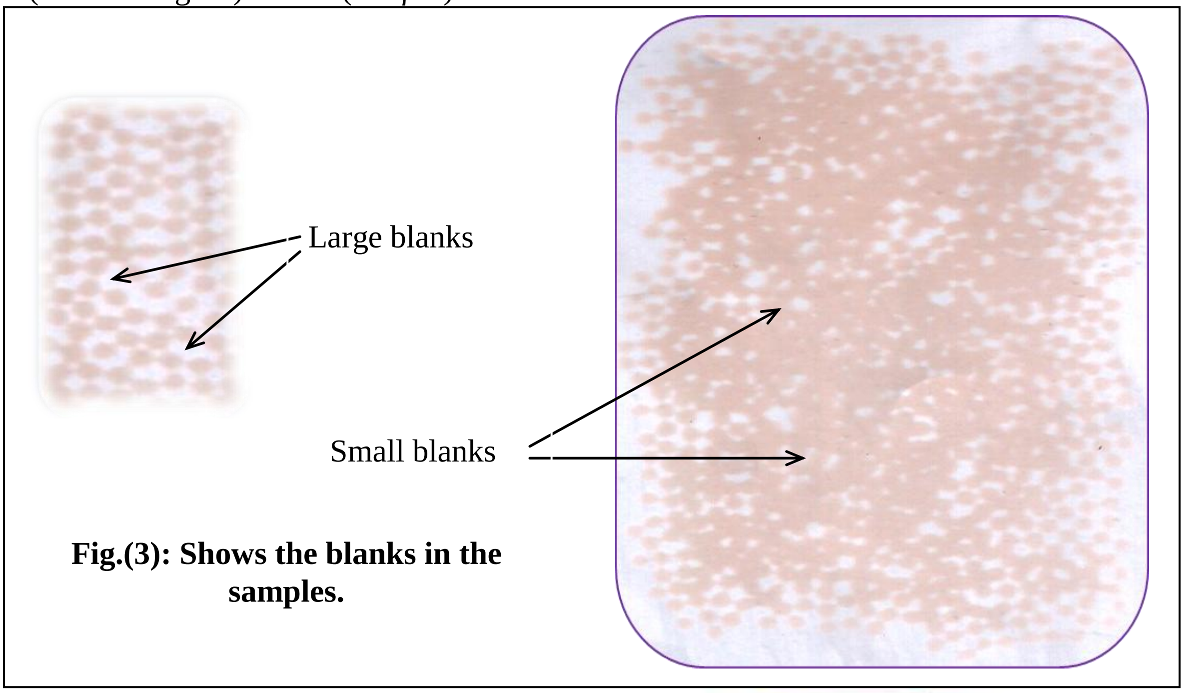
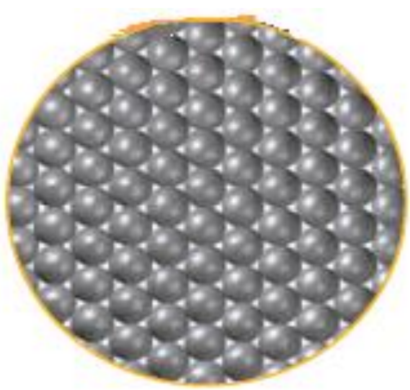
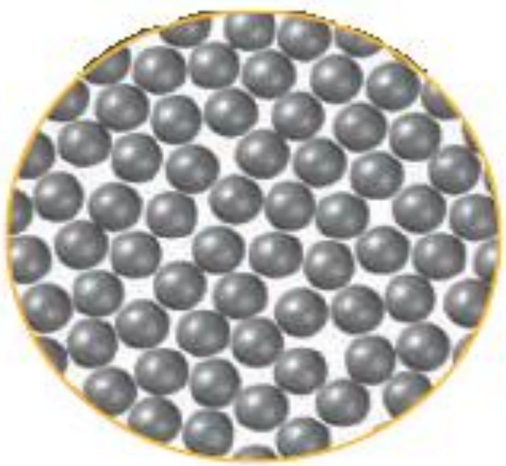


Fig.(3): Shows the blanks in the samples.



A. particle size 1mm



B. particle size 2.5mm

Fig.(4): Particles for the same weight but different size.

In the case of the big particle size absorber however the blanks between particles are large and hence the chances of interactions are reduced. In other words the radiation has a greater probability of being transmitted through the absorber and the attenuation is consequently lower than in the small particle size case.

Concliuion:

The results showed that particle size of (200µm) had no significant differences with lead sheet, so that one can use lead powder loaded polymer or elastomer sheets for manufacture radiation shielding aprons and coverings.

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اعتماد معامل امتصاص أشعة كاما على حجم دقائق الرصاص

حيدر سليم حسين   *عبد الحسين عبد الأمير البياتي*

حارث ابراهيم جعفر

*قسم الفيزياء- كلية العلوم – جامعة بغداد

الخلاصة:

تم دراسة اعتمادية معامل امتصاص أشعة كاما على حجم دقائق الرصاص والتي تتراوح أحجامها من 200مايكرومتر ولحد 2,5ملم . وباستخدام أوزان مختلفة لكل حجم. بينت النتائج بأن معامل امتصاص أشعة كاما تتناسب عكسيا مع حجم الدقائق بسبب تقارب الدقائق وتناقص المسافة البينية بينها.