Calculation the mass attenuation coefficient of beta-particles through Polyvinyl chloride

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Abstract

The mass attenuation coefficient for beta particles through pure Polyvinyl chloride (PVC) and flax fibers- reinforced PVC composite were investigated as a function of the absorber thickness and the absorber to source distance. The beta particles mass attenuation coefficients were obtained using a NaI(Tl) energy selective scintillation counter with ^{90}Sr/ ^{90}Y beta source having an energy range from (0.546-2.275) MeV. Pure PVC polymer samples were prepared by compacting the PVC powder in a mould at high pressure (10bar) and temperature about 140°C for 30 minutes. A hot press system was used for this process. The experimentally obtained values of mass attenuation coefficients for ^{90}Sr and ^{90}Y were found to be 7.72 $cm^2.g^{-1}$and 0.842 $cm^2.g^{-1}$ respectively, and the measured mass attenuation coefficients values decrease with increase of the absorber to source distance .

Keywords
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حساب معامل التوهين الكتلي لجسيمات بيتا خلال بولي كلوريد الفاينيل

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الخلاصة

تمت دراسه معامل التوهين الكتلي لجسيمات بيتا خلال عينات من مادة بولي كلوريد الفاينيل (PVC) ومتراكب الياف الكتان المدعمة بــ (PVC) كدالة لسمك المادة الماصة وللمسافة بين المادة الماصة والمصدر المشع. تم قياس معامل التوهين الكتلي لجسيمات بيتا باستخدام منظومة الكاشف الوميضي NaI(Tl) مع مصدر أشعة بيتا ^{90}Sr/^{90}Y بمدى طاقة تتراوح بين (0.546-2.75) ميكا الكترون فولت. حضرت عينات (PVC) النقي عن طريق كبس مسحوق الـ (PVC) في قالب معدني تحت ضغط عالي مقداره 10 بار وبدرجة حرارة 140 درجة مئوية ولمدة 30 دقيقة ولقد استخدمت منظومه الكبس الحراري لهذا الغرض. وجد ان القيم العملية المستحصلة لمعامل التوهين الكتلي لـ ^{90}Sr و ^{90} Y هي 7.72 $cm^{-2}.g^{-1}$ و 0.842 $cm^{-2}.g^{-1}$ على التوالي. وان قيم معاملات التوهين الكتلي تتناقص مع زيادة المسافة بين المادة الماصة والمصدر.

Introduction

The shielding of radiation is an important issue, especially with regards to human safety. How much and what type of material should be used to adequately stop various forms of radiation must be known. Low Z material like polyvinyl chloride (PVC) were one of the most widely used in radiation shielding from beta-particles sources and manufacturing shielding cloths from directly emitted ionizing radiation, due to abroad rang useful properties such as stability, weatherobility, inertness to many media, inherent flam, microbial resistance and low cost[1]. PVC is thermoplastic polymer; it is constructed of repeating vinyl groups having one of their hydrogen's replaced with a chloride atom. PVC itself is rigid but the addition of plasticizer make it soft, it is commonly used in clothing, to make flexible hoses, tubing, flooring, to roofing membranes and electrical cable insulation [2].

Here, we will study the rate of beta particles attenuation using various thickness of PVC polymer and measured the mass attenuation coefficient for PVC composite which have different layers of flax fiber as a function of the attenuator to source distance, using $^{90}Sr/^{90}Y$ source of beta particles with energy rang between (0.546-2.275)MeV.

Sample preparation

The samples were prepared by compacted different weights of PVC powder in cylindrical die under appreciably high pressure (10bar) and temperature about 140°C for 30 minute, the die then cooled to room temperature by tapped water and pressure was released gradually during the cooling cycle. For this process hot press system, equipped with pressure gauge, temperature controller, and water cooling path have been used. The samples were disc like shape of diameter about 3cm and thickness ranged between (0.1-0.6) cm. The PVC composite also prepared by compacted one, three and six layers of flax fiber between two discs of PVC samples on the same condition with thickness of 0.2cm.

Measurement of beta-particles intensities

An experimental set up of narrow beam geometry is the best method to determine the mass attenuation coefficient μ_m. The distinctive feature of narrow beam is that only the source radiations, which traverse the specimen absorber without experiencing any interaction of any kind, reach the detector. For example, any scattered radiation is prevented from reaching the detector [3].

The attenuation coefficient of samples under investigation has been determined by usual attenuation equation:

$$I(x) = I_o e^{-\mu_m x_m}, \qquad (1)$$

where I(x) is the beta-particles intensity after the attenuator material, I_o is the initial intensity of beta- particles incident on attenuator materials, μ_m is the mass attenuation coefficient in units of ($cm^2.gm^{-1}$), and x_m is the attenuator material mass thickness in units of ($gm.cm^{-2}$) [4].

Beta-particles intensities behind PVC samples with different thickness have been measured. Measurements have been carried out using a collimated beam of pure beta source $^{90}Sr/^{90}Y$ with energy (0.546-2.274) MeV. The leakage beta-particles intensities behind the PVC samples have been carried out by using sodium iodide crystal NaI(TI) scintillation detector of dimension 2"×2". The incident and transmitted intensities were determined for fixed preset time at 200 sec in each measurement. Furthermore, the values of mass attenuation coefficient μ_m were calculated as a function of attenuator material to the source distance H_{AS}, when the attenuator sample was placed just above the detector. The H_{AS} can be changed between (8-24) cm.

Determination of beta-particles rang

The rang of beta-particles, for energy range $0.01 \le E \le 2.5$ MeV can be approximated by Baker and Katz [5], and Theodorsson [6]:

$$R = 4.12 E_{max}^{1.265 - 0.0954 \ln E_{max}}, \qquad (2)$$

Where E_{max} is the maximum beta-particles energy in MeV and, R is the rang of beta-particles in $kg.m^{-2}$. In case of $^{90}Sr/^{90}Y$, having maximum beta energy 2.28 MeV, the value of beta-particles rang was found to be $10.534 kg.m^{-2}$. Therefore, when the thickness of the attenuator is above the rang of beta-particles the transmitted particles would be nearly stopped, for PVC polymer which has the density of 1390 kg/m^3, the thickness of PVC would nearly stopped beta-particles was 0.78 cm.

Result and Discussion

Beta particles are attenuated in an absorption medium by the various interaction processes, primarily through ionization and radiative energy losses. In Fig.(1) the transmitted beta-particles I(x) was displayed as a function of PVC mass thickness for $^{90}Sr/^{90}Y$ with energy (0.546-2.275)MeV. As can be seen from this figure that the count rate decreases rapidly as the PVC mass thickness increases. Because of the equilibrium mixture of both radionuclides in $^{90}Sr/^{90}Y$ beta source, it is not possible to evaluate the mass absorption coefficient through Eq. (1). Therefore we assume that the count rate through the external attenuators of thickness x is represented by the following fitting equation [7]:

$$I(x) = \frac{I_o}{2}\left(e^{-\mu_{Sr90} x_m} + e^{-\mu_{y90} x_m}\right) \qquad (3)$$

The number of points for each fitting were chosen depending on the range of bets particles from ^{90}Sr and ^{90}Y according to the Eq.(2). The values of mass attenuation coefficients for ^{90}Sr and ^{90}Y were found to be 7.72 $cm^2.g^{-1}$and 0.842 $cm^2.g^{-1}$ respectively.

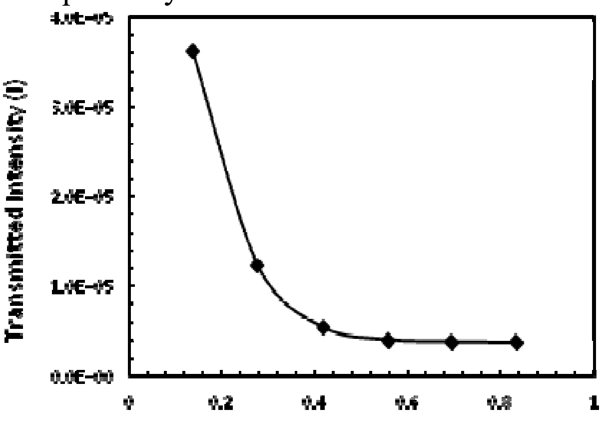

Fig.(1): Variation of transmitted beta-particles versus PVC mass thickness

The mass attenuation coefficients for PVC samples as a function of the mass thickness were shown in Fig.(2). Inspection of this curve revealed that the μ_m values decreases as the mass thickness increased.

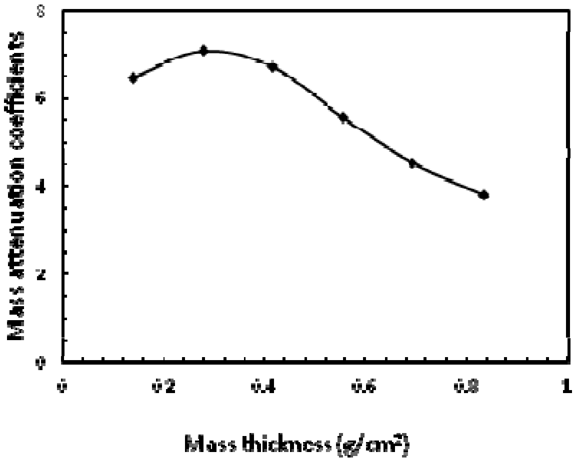

Fig.(2): Variation of mass attenuation coefficients od beta particles versus PVC mass thickness.

The change of μ_m depending on H_{AS} (from 8 cm-24 cm) for PVC and one, three and six layers of flax fiber- reinforced PVC composite were given in Figs 3 and 4. The measured μ_m values of pure PVC sample are in 11.927 $cm^2.g^{-1}$ to 3.8002 $cm^2.g^{-1}$ for H_{AS} 8 cm and 24 cm respectively. These Figs show that the μ_m values decrease with the increased of H_{AS} , this behavior can be explain on the bases of the mean path length (in the absorber) ,will be longer than real absorber thickness[8].It is clear from the Figs(3,4) ,that the values of μ_m for PVC less than for one ,three ,and six layer of flax fiber- reinforced PVC composite ,at the same distance from the source this result might be explain by the fact of the heterogeneity of filled PVC ,which causes many collisions.

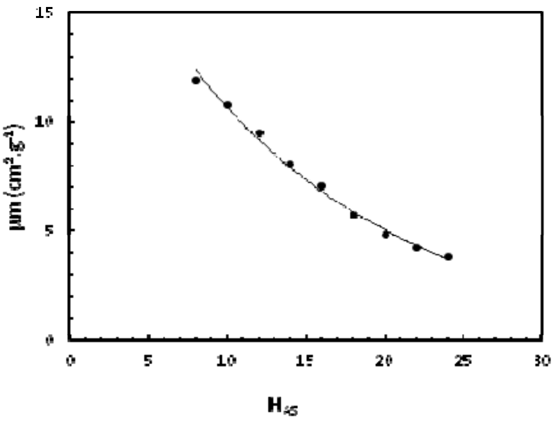

Fig.(3): Variation of the mass attenuation coefficients of beta particles versus H_{AS} for PVC.

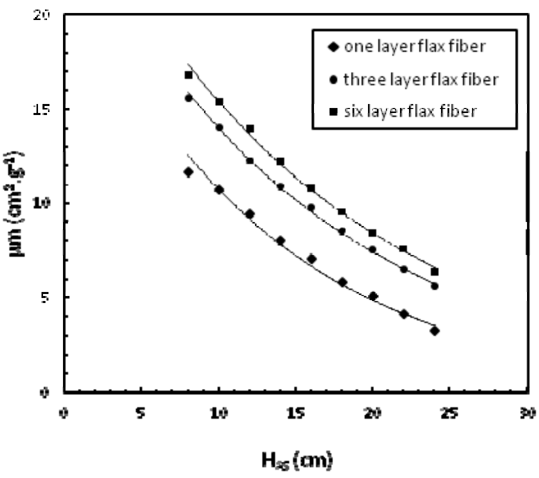

Fig.(4): Variation of the mass attenuation coefficients of beta particles versus H_{AS} for (one, three and six layes of flax fiber reinforced by PVC.

Conclusion

The values of mass attenuation coefficients for ^{90}Sr and ^{90}Y were found to be 7.72 $cm^2.g^{-1}$and 0.842 $cm^2.g^{-1}$ respectively. The μ_m values decrease with the increased of H_{AS} for PVC and one, three and six layers of flax fiber - reinforced PVC composite. For PVC the values of μ_m less than of flax fiber-reinforced PVC composite at the same H_{AS}.

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