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Calculation of Radiation Doses Using Shields for Nanoparticles Tungsten Oxide WO3 Mixed with Epoxy

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Abstract: In this work, we have study the radiation dose for shielding properties against gamma ray with energy (662 Kev) emitted from the isotopes of Cs-137 and with Energies (1172 and 1332 KeV) emitted from the isotopes of Co-60. The shielding was content from Epoxy (Ep) resin matrix filled with different concentrations and thickness of Nano-WO3 metal powder as reinforcements. The dose rate and dose reduction percentage of the gamma ray was measured and calculated by using a detector (UltraRadiac™-Plus).Results showed that the highest dose reduction was 46.15% and 34.31% for Cs-137 and Co-60, respectively, at 40% concentration for all samples. We note that dose values decrease with increased concentration and thickness of samples. The polymer is used as a base material for the shield, which increases its strength and elasticity. The additions of nanomaterial have physical characteristics worked attenuation of the radiation. Thus the materials are lightweight and high intensity and suitable for use as shields for gamma radiation.
Keywords: Dose rate, Dose reduction, Radiation, Attenuation, Shielding.

1 Introduction

Radiation is defined as to have energy passing through the physical medium and space. The nucleus is classified as ionizing and nonionizing depending on the energy of the self-transformation that happens. The ionizing radiation like alpha, beta particles and X-ray, gamma has high energy while non-ionizing radiation has low energy. The radiation with high energy can ionize atoms of the interacting matter.

For the purpose of protecting humans and the environment from the effect of high ionizing radiation, suitable shields are used with high efficiency to absorb radiation. Shielding is one of the most effective radiation protection methods; others include time and distance. With shielding, radiation dose can be lowered to a desired level [1-5]. For shield designs, gamma ray was one of the main types of nuclear radiation, which have to be considered; since any shield attenuates the gamma rays will be more effective for attenuating other radiations [6]. Each type of radiation is known to have physiological properties that need a particular shield. As a result of the scientific development in the world of materials, the search for shields those have flexible mechanical properties, with low cost, economical availability and non-toxicity. Especially for radiation gamma and X-ray. Due to the development in the world of materials, especially in the manufacture of nuclear shields such as traditional lead, there is a tungsten material that has high specifications and suitable in the manufacture of shield.

In view of this, many researchers have taken of the polymeric matrices of high density, flexibility and lightness in improving the properties of shields. Where Nano materials were used as usable filler materials with polymer matrixes in literature [7-8]. Protective materials with Nano particles have shown to have good mechanical properties to be used in developing radiation shields. The size and concentration of Nano-particles used in making radiation shields are two important factors affecting the radiation attenuation properties of the protective materials [9-12]. They also used [13-15] Nano materials as a booster to reduce radiation doses in areas that affect the safety of radiation workers, that is we get the least radiation dose from the shield and the least cost, where they got good results.

In this study some metal polymer composites were produced and their gamma radiation shielding effects were investigated. Commercial Epoxy was used as matrix material of the composites and filled with different amounts of powdered Nano tungsten oxide (WO3). The produced composites were tested gamma spectrometrically to determine their radiation shielding capacities and the radiation dose rate was measured using personal dose dosimeters. Styles [15-16].

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2 Theoretical

The study of radiation doses depends mainly on the three golden rules of distance, time and shields, including the nature of the materials used in the type of radiation, and since the current study is based on the radiation of Gamma -ray, where the interactions of radiation with the material into three types is the Photoelectric Effect , Compton Scattering and Pair Production, as well as the effect of factors , Such as the density of materials used as well as the cross section of the used element. All these factors affect the amount of radiation dose [16-19].

2.1 Radiation Shielding

A shield is a physical structure interposed between a Radiated source of ionizing radiation and an area to be protected which leads to decrease the radiation plane at the position of that area. Lead is the most costly and effective material used as radiation shield Due to of its high density, high resistance to chemical corrosion, large atomic number and easy to fabricate. However, lead is very expensive and is not common hence there is a restriction to its availability as radiation shield. We used in the present study nanomaterial represented by tungsten oxide, which has the characteristics of physical near to the lead in the atomic number and density and light weight in addition to the low cost and flexibility. Gamma radiation shielding is the attenuation and absorption of gamma energy in shielding material. Most materials absorb the energy of gamma rays to a certain degree. The range of attenuation depends on the thickness and density of the shielding material. The scale useful of shielding property is the mass per unit area of material. Hence a thick layer of a lighter material will have the same effect as a thin layer of a denser substance. Radiation Shielding is used to reduce the radiation exposure to personnel and equipment in the proximity of radiation sources. It is called biological and thermic shielding, respectively.

2.2 General Safety Requirements

The fundamental safety purpose is to protect environment and the people from threatening effects of ionizing radiation. This purpose must be achieved without unduly set the operation of facilities or the conduct of activities that give high to radiation risks. Therefore, the system of protection and safety aims to assess, manage and control exposure to radiation so that radiation risks, including risks to the environment and risks of health effects, are reduced to the range reasonably achievable. These standards are grounded on the various safety principles declared in the fundamental safety principles [IAEA], [20].

The guiding precept throughout this manual is the Principle which instance that the doses received by members of the public and workers be kept As Low As Rationally Achievable (ALARA), economic and social factors taken into account. And the three basal methods used to reduce the foreign radiation danger are time, distance, and shielding. The dose limit for non-nuclear energy workers and members of the audience is 1mSv in one calendar year. The ALARA principle applies and every effort must be made to reduce the actual doses received by non-nuclear energy workers to as low a level as potential [21].

2.3 The Gamma-Ray Dose Rate Calculation

Dose rate (D') is defined as the ratio of an incremental dose, (dD) in a time interval (dt), As shown in the equation

$$D' = dD \;/\; dt, \quad [22].$$

We used the personal dosimeters to measure the dose rate of the gamma ray through the protective shield.

2.4 Reduction of Radiation Dose Calculation

Percent Reduction of radiation dose (%) values of the composite materials were also calculated for basic comparison of the dose reduction performances of the composites with each other. dose reduction calculations were done via $Eq.$ 1 quoted from [23].

$$Dose\ Reduction\ (\%) = \left[1 - \left(\frac{Measurement\ with\ shield}{Measurement\ without\ shield}\right)\right] x100 \quad \ldots\ldots\ldots (1)$$

3 Experimental

3.1 Measurement System

3.1.2 Personal Dose Dosimeters

The personal radiation detector can measure and display both the (Dose-Rate), the amount of radiation measured at the moment, and the total dose of the Dose since the last (dose) was cleared. In this work we used a personal radiometer (UltraRadiac™-Plus), The dose rate that can be measured ranges from (0.01 $\mu Sv \;/\; h$) to (2 $Sv \;/\; h$). Model (URAD-PLUS-S/Y), Made-up company (CANBERRA) USA.

3.1.3 Radioactive Source

Radioactive sources used in this study is to Cs-137 with Radiation activity (9.49 μCi) and a half-life of (30.17 y), which emits photons gamma of energy value (662 Kev), and Co-60 with Radiation activity (1 mCi) and a half-life of (5.27y), That emits photons gamma ray with two energies values (1172 KeV) and (1332 KeV).

3.2 Preparation of the Composites

We have been using epoxy ($C_{18}H_{24}O_3$) material negotiable hardening by adding hardener; a commercial product

(Epoxy UAE production) for the purpose of producing Shields is intended to be used in shielding against gamma rays.

The choice of epoxy among many polymers is due to many reasons, the most important that it can be manufactured in the form and dimensions as needed, and the second reason it is important is that the epoxy polymer is characterized by highly resistant against gamma rays [24-26] The component of powdered Nano-WO_3 as filler of the composite. This material was chosen for high atomic number, density and also suitable crystalline structure in the manufacture of nuclear shields.

The number of samples used in this study is 17 samples. It is made of epoxy as a base material and is supported by nanoparticle tungsten oxide and different filler concentrations (10%, 20%, 30%, 40%), different thickness (1,2,3,4 cm), epoxy Pure without any additions.

3.3 The Geometric Arrangement of the System

For the purpose of measure the gamma- ray dose rate of manufactured shields, two collimators were used to obtain the good geometric arrangement. these two Collimators made of lead material and dimensions (4×16×16) cm have centered circular hole with diameter (1 cm) to get collimated beam, and the distance between the detector and the radioactive source is (17 cm) for source Cs-137 due to the limited activity of the source, and at a distance of (30 cm) to source Co-60 due to its high activity.as in the Fig.1 that represents the good geometric arrangement.

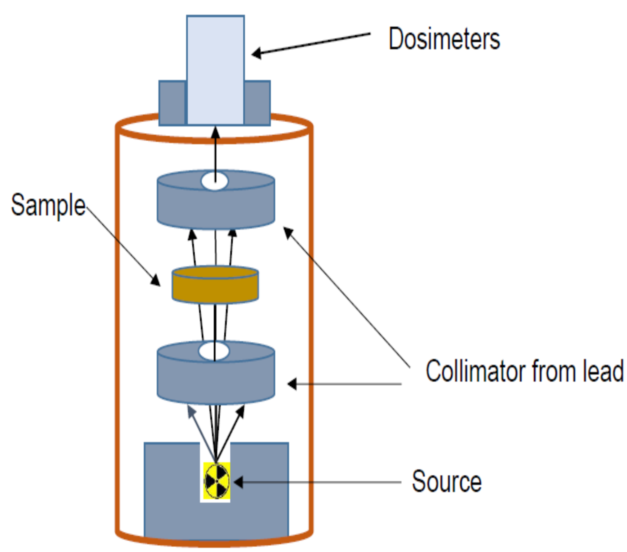


Fig.1. Geometrical arrangement of the measurement system

4 Results and Discussions

The Dose-Rate of gamma rays was measured and the dose reduction percentage was calculated. For both of the radiated source Cs-137 (662Kev), Co-60 (1172 and 1332 Kev) and results are summarized in Table1.

We note that there is a significant decrease in radiation dose rate values from these theoretical values due to the use of good engineering arrangement where the radiation beam is paid at a narrow angle because of the existence of the payments. The probability of dispersion of the photons of the charge packet is greatly reduced. Therefore, we must point out that the rate of support and the energy of the radioactive source play a major role in determining these effects. Therefore, a relationship was drawn between the measured and calculated irradiative dose rate for the irradiated exporters and the concentration of the promoter as in Fig. 2. We note from this figure that the dose values of the gamma radiation decrease as the concentration of the nanoparticle (WO_3), for the results summarized in Table 1. and for both exporters, because of increasing absorption coefficient when increasing the rate of support, which leads to the absorption of a large proportion of photons and thus reduce the radiation intensity of the source of radiation, as at the low rate of consolidation will increase the process of dispersion of photons and less absorption of either increasing the rate of consolidation, the absorption process will increase and decrease Probability of dispersion of photons, we also note that the fraction of photons scattered will increase with increasing energy.

A relationship was also drawn between the measured and calculated radioactive dose rate for the irradiated exporters and the sample thickness as shown in Fig. 3, We observe from this figure that the values of the radiation dose vary with the thickness of the sample, The rate of radiation dose decreases significantly when the thickness of the shield is increased, particularly at the high concentration and the two sources, due to the increased absorption of energy by the atoms of the material when increasing the thickness.

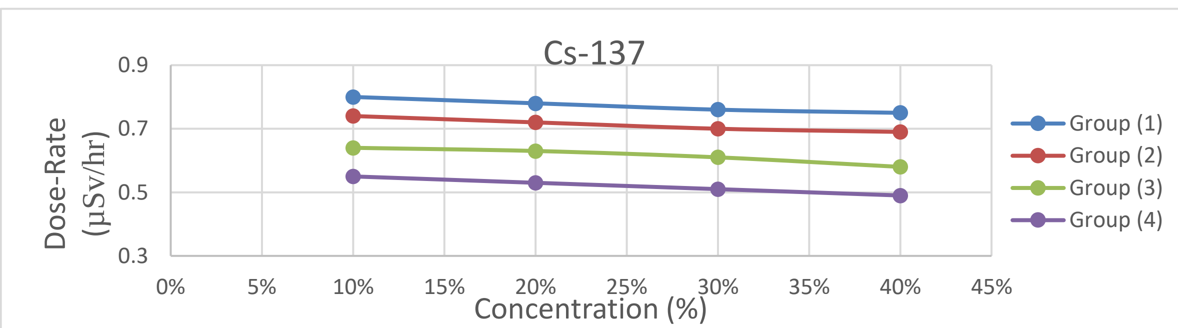
The above we noticed that, the gamma ray dose rate is decreasing with the shield thickness increasing. It is observed that the value of gamma ray dose rate for will decrease as the concentration of nanoparticles increases in shields. We notice that the values are decreasing slowly in a sample Group (1) and Group (2), but it is decreasing rapidly in both samples Group (3) and Group (4).

This means that when increasing the percentage of concentration and increasing thickness, there is a significant decrease in radiation dose values. Percent Dose Reduction (%) produced composites were calculated by using$Eq. 1$, as it is mentioned in Section 2.4, the eliminated results are summarized in Table 1 for both Cs-137 and Co-60. And as the percent Dose Reduction (%) performances for all the composites are shown in Fig.4. The performance of the matrix material (Epoxy) was increased with metal Nano - tungsten oxide (WO_3) filler additions.

We note that epoxy alone is not good for use as a protective agent for gamma rays. However, when adding the filler material (WO_3), we notice an increase in the percentage of dose reduction with increased concentrations,

Table 1: Comparison of gamma- ray dose rate for nanoparticles shield at different thickness and concentrations, and
Average dose reduction results. of radioactive sources (Cs-137, Co-60).

Group No.	WO_3 Concentrations	Thi. (cm)	Cs-137 (662 Kev)		Co-60 (1172-1332 Kev)	
			Dose-Rate $(\mu Sv/hr)$	Dose Reduction (%)	Dose-Rate $(\mu Sv/hr)$	Dose Reduction (%)
None	-	-	0.91	-	37.39	-
Ep (pure)	0	1	0.81	10.98	34.51	7.70
Group (1)	10%	1	0.80	12.08	33.67	9.94
	20%		0.78	14.28	33.39	10.69
	30%		0.76	16.48	32.88	12.06
	40%		0.75	17.58	31.69	15.24
Group (2)	10%	2	0.74	18.68	31.47	15.83
	20%		0.72	20.87	31.00	17.09
	30%		0.70	23.07	30.50	18.42
	40%		0.69	24.17	29.63	20.75
Group (3)	10%	3	0.64	29.67	30.77	17.70
	20%		0.63	30.76	29.08	22.22
	30%		0.61	32.96	27.86	25.48
	40%		0.58	36.26	27.09	27.54
Group (4)	10%	4	0.55	39.56	28.66	23.34
	20%		0.53	41.75	26.68	28.64
	30%		0.51	43.95	25.30	32.33
	40%		0.49	46.15	24.56	34.31



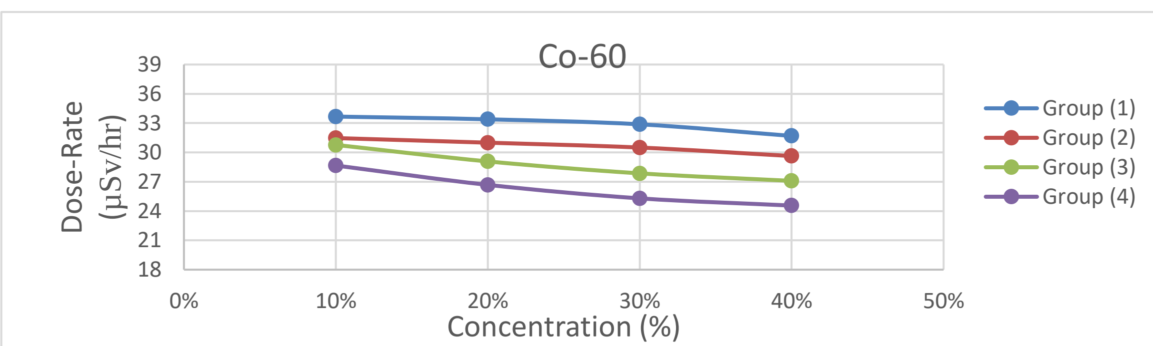


Fig.2. The dose measured after the Nano- structured shields for all composite samples as a functio of the concentration percentage (%) of WO_3 for Cs-137 and Co-60 gamma ray beam.

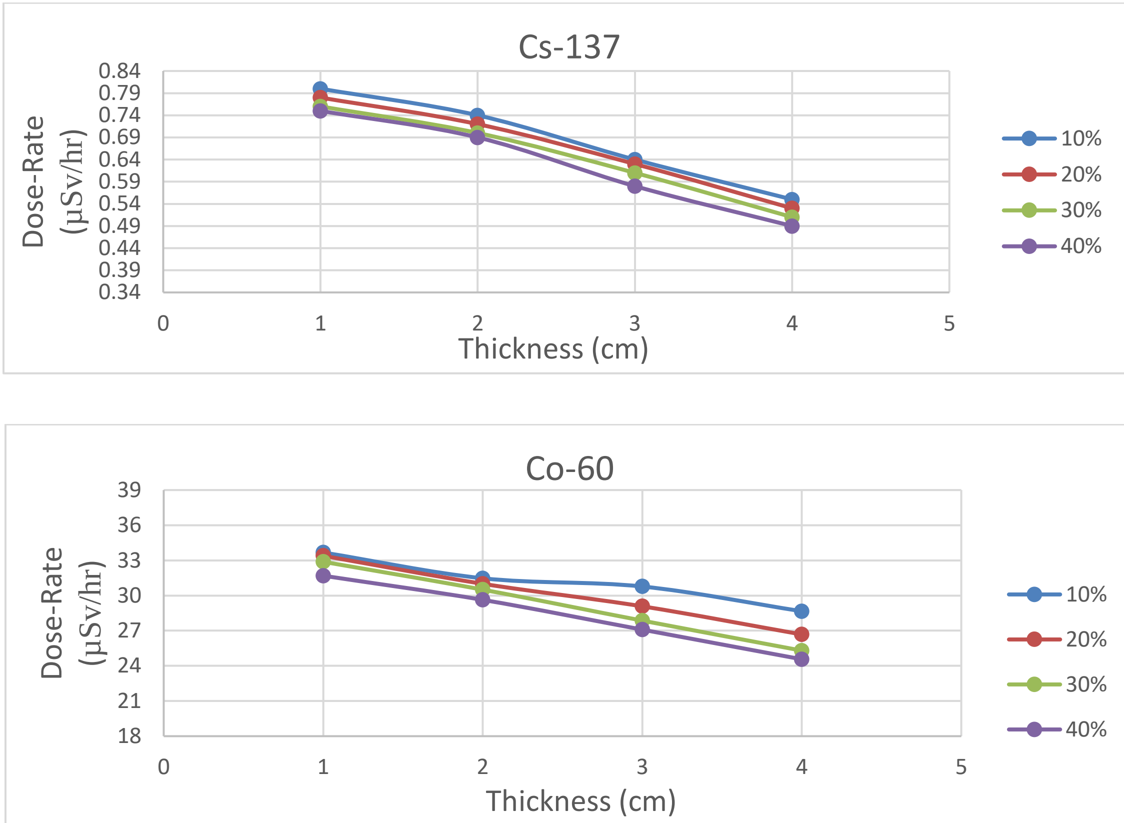


Fig.3. The dose-dose relationship of the sample thickness to Cs-137 and Co-60 for all concentrations.

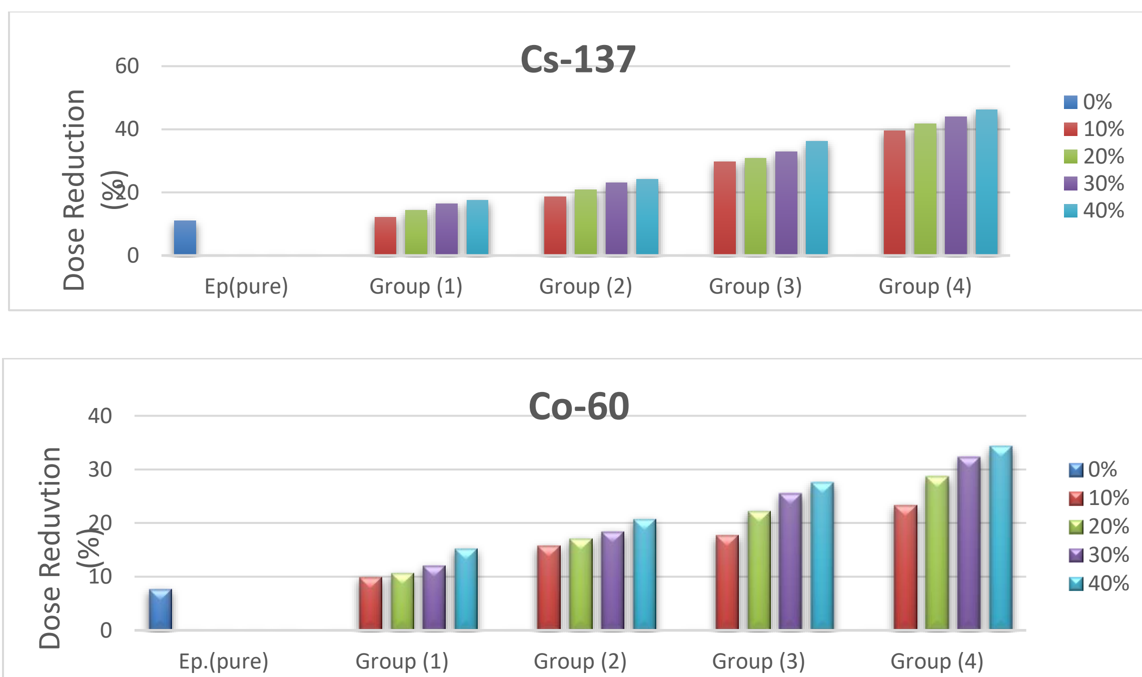


Fig. 4. Percent Dose Reduction (%) of the composites.

as well as a significant decrease in dose when thickness increases.

Where radiation dose was reduced by 10.98% and 46.15% for the irradiated source of gamma rays (Cs-137) and by 7.70% and 34.31% for the irradiated source of gamma rays(Co-60) by using shields made of Composites materials with different thicknesses and concentrations. We note that there is a clear effect of reducing the radioactive dose when increasing the concentration of (WO3) and thickness for all samples. We note that dose reduction rates have not been achieved at the same rates for exporters used, Because of the relationship between increasing energy values and the attenuation properties of Shield made, As the dose reduction rate decreases with increasing energy. From the above, we note that reducing the radiation dose depends mainly on the concentration of the material, the thickness of the shields and the source of radioactive energy.

5 Conclusions

The study showed that there is an improvement in the properties of the epoxy material towards the shielding of gamma ray through the addition of the Nano-tungsten oxide and certain ratios and thickness. Characterized the produced composites by strength and mechanical durability and has the ability to stick. Nanoparticle tungsten Oxide has high flexibility, light weight, high resistance and high density for the manufacture of radiation shield as well as high mechanical specifications compared with conventional shielding material lead which has high toxicity. The results showed that the radiation dose rate of gamma ray, and the dose reduction rate is affected by the increase of the percentage of the support and thickness, where it was found that the effectiveness of the shield would be better in case of increased concentration of thickness. These shields can be used in various fixed and portable applications because of their light weight. Special clothing can also be manufactured for the radiation of these materials, and are especially suitable in X-ray room to protect workers and patients. Thus, the results are important in the field of medical, research and economic, especially in the protection of the environment and thus protect people

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