Using X-Ray Films for Evaluation efficiency of Unsaturated Polyester Reinforced by Lead Oxide as Shielding for Medical X-ray Devices

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Abstract

The largest use of x-ray in medical by dentists, employers or persons that needed by patients with specific conditions, lead to higher exposure of x-ray that may cause many diseases. In the present work radiography films have been used in evaluating the efficiency of using unsaturated polyester polymer reinforced with lead oxide (PbO) as shield material for medical x-ray devices, many parameters studied like concentration and thickness that they are increasing the attenuation of x-ray in them. The results show that the attenuation of X-ray increasing with concentration of reinforced material and with thickness, and the optical density decreases with increasing concentration from 0% to 50%, we chose 30% as suitable concentration to increase thickness from 1-6 cm that shows 3cm is suitable to manufacture shield for medical devices, that we have concluded that these materials very effective in attenuated x-ray, which can fabricate in any shape we needed in multi-situations and for this purpose radiography film method was used to appear these effects and suitable more than electric equipment that cannot use in these measurements.

Key Words: X-Ray, Attenuation, Reinforced, Radiography, The Shield Material.
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Introduction

X-ray is electromagnetic radiation that classified as soft with an energy range of 120 eV to 12 keV and hard with an energy range of (12-120 keV) that can highly penetration that can used in diagnostic radiography, which can produce radiographic image (Novelline, 1997, Kehinde et al., 2017).

Rontgen discovers that x-ray can used in medical imaging by identifying bone structures. That made it a good tool in diagnostic in addition to other technique and become a part of medicine (Spiegel, 1995).

General radiography is one of the most widely used radiation Checkups among radiographic imaging systems. The radiation dose associated with each of the checking is small, but the radiation risk to the population should be minimized when applying these techniques widely to the minimum possible, which is one of the most fundamental principles of the radiological experiment. On this basis, a set of techniques has been developed to meet this requirement in general radiography, for example shielding (MacKay et al., 2012).

Based on data from experimental studies, x-ray imaging is relatively safe and relatively low radiation exposure, but there is a threshold for the cumulative dose of radiation per year that the patient should not exceed to prevent the risk of cancer (Upton, 2003).

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The diagnostic x-ray exposure amounts to about 14% of the total annual exposure to radiation from It is estimated that the risk of cancer increases when exposure to an additional cumulative dose of radiation by 0.6 to 1.8% (de Gonzalez A. B. and Darby S., 2004). The amount of radiation absorbed depends on the type of X-ray diagnosis as well as the part of the target body (Brenner and Hall, 2007). Shielding is considered one of the most important methods of radiation protection in addition to distance and time, whereby using appropriate shielding the radiation dose can be reduced to the required level while noting that each type of radiation has certain materials for shielding design(Mahdi et al., 2017).

Designed shields from lead are considered the most common shields to reduce the exposure of X-rays because of high lead density, ease of installation, low cost and he has the high stopping power. The x-ray photon has high interaction probability and thus the shielding of photon beam is therefore exponential (Alchemy Art Lead Products, 2008).

Many factors that affect in choosing shield material like thickness, weight, attenuated factor and resistance to radiation damage (Mackenzie D., 2010).

The aim of this work is how we can use the radiography films in evaluating the efficiency of using unsaturated polyester polymer reinforced with lead oxide (PbO) as shield material for medical x-ray devices, many parameters studied like concentration and thickness that they are increasing the attenuation of x-ray in them.

Materials and Methods

The samples of the absorbent material (composite reinforced with lead oxide (PbO)), which were prepared with different concentrations of (0,10,20,30,40,50)% with dimensions of (10x10cm) and thickness of (1,2,3,4,5) cm. The concentrations were calculated using the following equation (Mkhaiber, 2012).

$$\Psi = \frac{W_f}{W_c}\, x\ 100\% \qquad (1)$$

$$W_c = W_f + W_m \qquad (2)$$

The X-ray device, type SMS-BT-4, manufactured by the Korean company (ECORAY) was used, which is existing in the Kadhimiya Governmental Hospital, with a maximum voltage of 150 kV, we chose energies(70, 80, 90, 100) with 200mA the normal energy which used for recording the intensity of the radiation through the absorbent material.

For recording X-ray films type Kodak Film with dimensions of (24x30) cm were used for exposure, which manufactured by Kodak company, and DRYSTAR films type DT2B, which manufactured by a Belgian company and AGFA for a process the showing with dimensions(35x43 cm).

The devices arranged as in Figure 1, where the collimator with a diameter of (15 mm) has placed before the absorbent material, In front of the X-ray device to obtain a homogenous energy beam, the absorbent material was placed directly after the collimator with contact on it, as the films were placed at a distance of (15 cm). First, we are recording the intensity of the radiation without the absorbent material, then the absorbent material with a concentration of 0% (i.e. only the polymer without the reinforced material) was placed to record the falling radiation on the film. The previous step has been repeated for each concentration of the reinforced material (10,20,30,40,50)%.

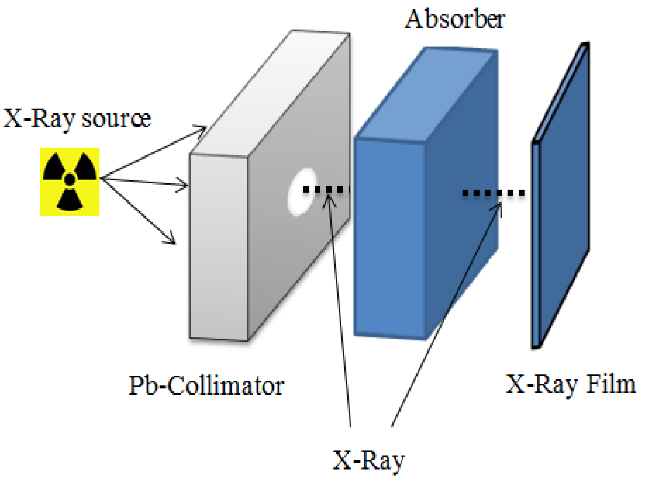

Figure 1. Order of equipment used in the measurement process

After fixing the films, and through the results of step (2), the concentration (30%) was chosen as the most suitable concentration and with good mechanical properties. Different thickness (1,2,3,4,5) cm was selected for the same concentration of 30%, then we recorded the intensity of the falling x-rays on the films.

The films were fixed, then the intensity of the optical density was calculated using U.S.A. device, Type X-Rite 301 Transmission Densitometer for accurate measurement of film that recognizes it as the industry standard.

The current intensity was changed in case of 90kV and for two values (200 and 320 mA), which was significantly used in the hospital.

The X-Com program was used to calculate the mass attenuation coefficient for all samples, which we can generate attenuation coefficients and cross sections for the different elements, mixtures or compounds for multi-energy in the range of 1 keV - 100 GeV (Mkhaiber and Abdulraheem, 2015).

Results and Discussion

The relationship between the optical density and the concentration at different energies was studied as shown in Table1.The table shows that the optical density decreases with increased concentration at the same energy, this means that the attenuation of X-ray will be greater as shown in Figure 2. This can be explained by the fact that with increased concentration, x-ray interaction with the material will increase, so the absorption of the shield to this radiation will increase. From these results, we have chosen the concentration of 30% as a suitable concentration which was in agreement with reference (Mkhaiber, 2012).

Table 1. The values of Optical density at different concentrations.

Concentration	Optical density (70kV)	Optical density (80kV)	Optical density (90kV)	Optical density (100kV)
0%	1.85	1.85	1.85	1.85
10%	1.82	1.84	1.85	1.85
30%	1.8	1.82	1.84	1.85
50%	1.12	1.73	1.83	1.84

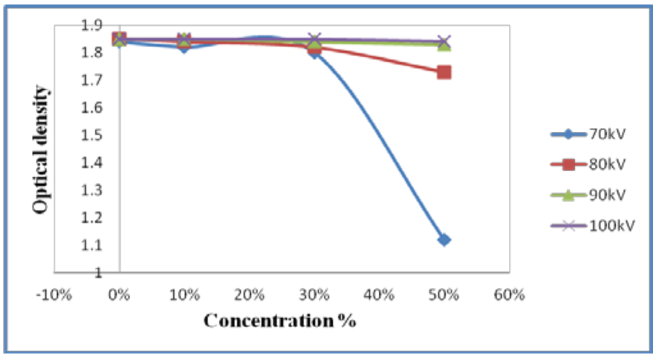

Figure 2. Optical density as a function of concentrations at different energies

Table 2 shows the relation between optical density and the thickness of the absorber. The table shows that the values of optical density decrease with the increase of thickness at the same energy, as shown in Figure 3.

Table 2. Optical density with a thickness of concentrations for multi-energies

Thickness	Optical density (70kV)	Optical density (80kV)	Optical density (90kV)	Optical density (100kV)
1	1.84	1.85	1.82	1.8
2	1.83	1.84	1.68	1.15
3	1.78	1.85	1.39	1.13
4	1.57	1.8	1.18	0.1
5	1.37	1.78	1.08	0
6	1.17	1.61	0	0

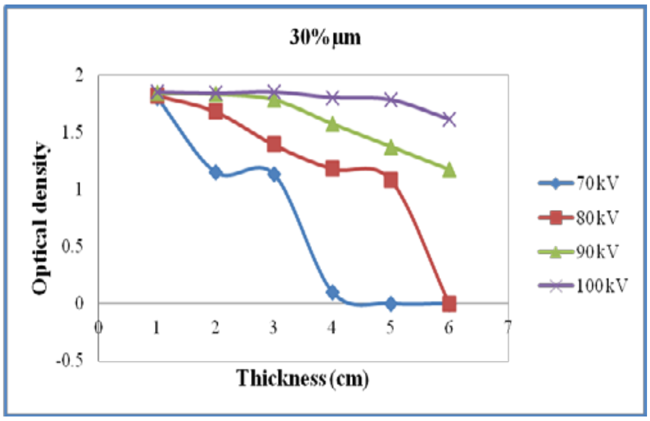

Figure 3. Optical densities with thickness for multi-energies for 30 % concentration

The theoretical values of the linear attenuation coefficients of these shields were also calculated using the Xcom program as shown in Table 3. The result shown that, when concentration increased the values of X-ray attenuation will increase at the same energy.

Figure 4 shows the relationship between attenuation coefficients and energy. From this figure we observe that there is a fluctuation in the attenuation coefficient behavior with increasing energy, The electron K shell will removed from an atom when it gets a mount of energy equal to its binding energy from the photon , strong resonance absorption occurs. That made the attenuation cross section highly increase and called absorption edge. Increasing photon energy will decreasing the probability of photoelectric and Compton interactions.

Table 3. Linear absorption coefficient with energy, calculated by X-Com program.

E(MeV)	μ (cm^{-1}) 10%	μ (cm^{-1}) 20%	μ (cm^{-1}) 30%	μ (cm^{-1}) 40%	μ (cm^{-1}) 50%
0.07	0.637	1.159	1.810	2.643	3.747
0.08	0.505	0.878	1.343	1.937	2.736
0.09	1.115	2.234	3.636	5.430	7.809
0.10	0.891	1.753	2.826	4.199	6.020
0.11	0.735	1.411	2.254	3.330	4.757
0.12	0.622	1.164	1.842	2.715	3.852

Table 4. Mass absorption coefficient with energy, calculated by X-Com program.

E (MeV)	μ_m (cm^2/g) 10%	μ_m (cm^2/g) 20%	μ_m (cm^2/g) 30%	μ_m (cm^2/g) 40%	μ_m (cm^2/g) 50%
0.07	0.4996	0.82	1.14	1.46	1.78
0.08	0.3964	0.621	0.846	1.07	1.3
0.09	0.8747	1.58	2.29	3	3.71
0.10	0.6994	1.24	1.78	2.32	2.86
0.11	0.5769	0.998	1.42	1.84	2.26
0.12	0.4878	0.823	1.16	1.5	1.83

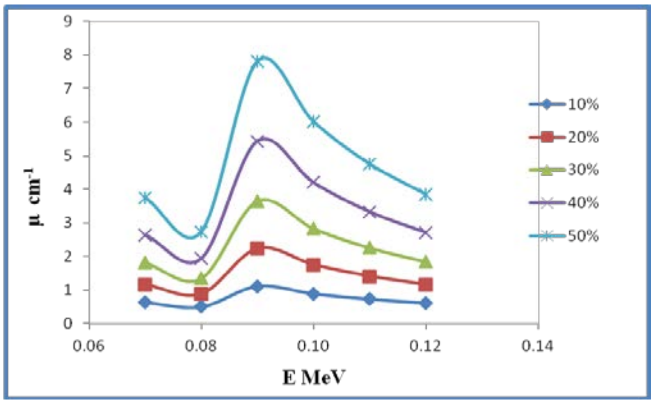

Figure 4. Linear absorption coefficient with energy, calculated by the X-Com program for different concentrations.

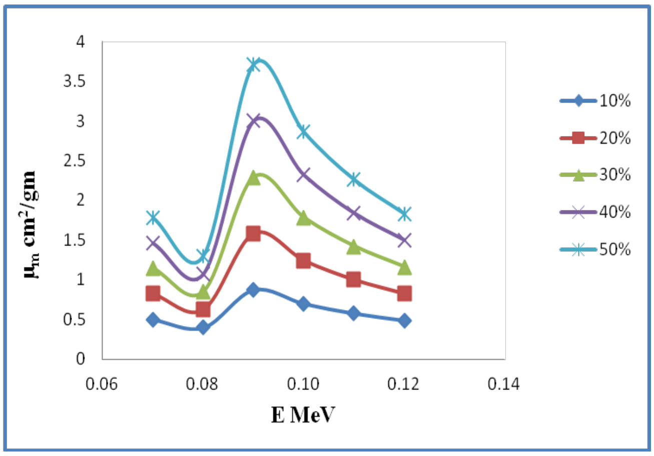

Figure 5. Mass absorption coefficient with energy, calculated by the X-Com program for different concentrations.

From Table 5 and Figure 6 we note that the optical density decreases with increases of concentrations for the same energy but with different currents.

Table 5. Optical density with concentrations for energy 90 kV with a current of (200, 320) mA.

Concentration	Optical density 200 mA	Optical density 320 mA
0%	1.82	1.85
10%	1.8	1.85
30%	1.74	1.84
50%	1.65	1.83

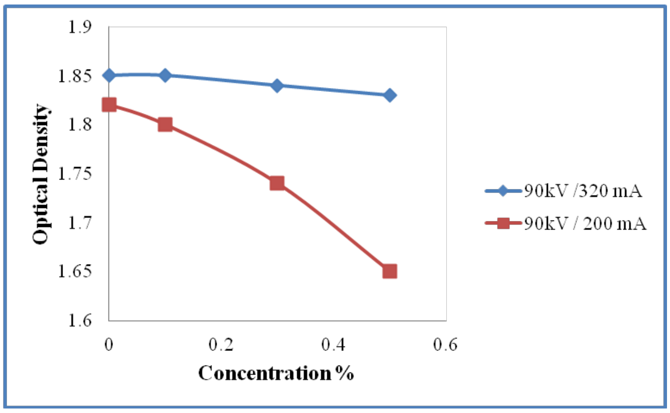

Figure 6. Optical densities with concentrations for energy 90 kV with a current of (200, 320) mA.

Conclusions

The radiological films were an effective method for real measurement more than electrical detectors that cannot count the x-ray at the short time (second) as in medical x-ray devices.

All the results were in agreement with many researchers (Mkhaiber and Abdulraheem, 2015) that the attenuation increasing with increasing of material by concentrations and thickness.

Using polymer reinforced with heavy metals allows us to choose the right concentration and thickness to make shielding materials with good specifications, such as lightweight, cheap and higher Attenuation with any shape that can be fixed with the x-ray device, which can be placed around the X-ray device for protection in cases while the required another person in addition to the patient or existence like a dentists or patient's companion in situations where the patient can not only be present.

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